NASA Technical Memorandum 89049

Spin-Tunnel Investigation of a 1/15-Scale Model of an Australian Trainer Airplane

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NASA
National Aeronautics and Space Administration

Scientific and Technical Information Branch

1987

Summary

An investigation has been conducted in the Langley Spin Tunnel to determine the spin and spin-recovery characteristics of a 1/15-scale model of an Australian trainer airplane. The investigation included erect and inverted spins; configuration variables such as a long tail, fuselage strakes, 20° elevator cutouts, and rudder modifications; and determination of the parachute size for emergency spin recovery. Also included in the investigation were wing leading-edge modifications to evaluate Reynolds number effects.

The results of the investigation indicate that the basic configuration will spin erect at an angle of attack of about 63° at about 2 to 2.3 seconds per turn. Recovery from this spin was unsatisfactory by rudder reversal or by rudder reversal and ailerons deflected to full with the spin. The elevators had a pronounced effect on the recovery characteristics. The elevators-down position was very adverse to recoveries, whereas the elevators-up position provided favorable recovery effects. Moving the vertical tail aft (producing a long tail configuration) improved the spin characteristics, but the recoveries were still considered marginal. An extension to the basic rudder chord and length made a significant improvement in the spin and recovery characteristics. Satisfactory recoveries were obtained by deflecting the rudder to full against the spin and the elevators and ailerons to neutral.

Inverted spins were obtained for only the prospin control configuration (that is, rudder with the spin, stick forward, and ailerons deflected to roll in the opposite direction of the spin), and recoveries were rapid by deflecting the rudder to full against the spin and moving the ailerons and elevators to neutral.

Other items such as the dorsal fin, open canopy, an elevator cutout of 20°, and fuselage strakes had no effect on the spin and recovery characteristics. Also, moving the center of gravity forward had little or no effect on the developed spin and recovery characteristics.

The parachute size recommended for emergency recovery for all erect spins on the airplane is 11.3 ft in diameter with a line length of 25 ft (the distance from the attachment point to the canopy) and having a drag coefficient of 0.5 (based on the laid-out-flat diameter). This parachute will also provide recoveries from all inverted spins provided the rudder is moved to neutral at the time that the parachute is deployed.

Model tests were made with a small Krueger flap on the leading edge of the wing to evaluate possible Reynolds number effects. The results of these tests showed that the spin and recovery characteristics were similar for the model with or without the Krueger flap, a condition indicating that the Reynolds number effects are fairly small for the test configuration and that the model results are representative of the airplane spin and recovery characteristics.

Introduction

At the request of the Department of Defense, an investigation has been conducted in the Langley Spin Tunnel at the NASA Langley Research Center to determine the spin and recovery characteristics of a 1/15-scale model of an Australian trainer airplane. The investigation included erect and inverted spins, various configuration variables, and determination of the parachute size for emergency spin recovery. Power was not simulated on the model.

Symbols

b	wing span, ft
C_D	drag coefficient of parachute based on laid-out-flat area, $\frac{\text{Drag}}{(1/2)\rho V^2 S_p}$
$\bar{c}$	mean aerodynamic chord, in.
I_X, I_Y, I_Z	moment of inertia about X, Y, or Z body axis, respectively, slug-ft^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ℓ	distance from skirt of uninflated parachute canopy to towline attachment point on airplane, ft
m	mass of airplane, slugs
S	wing area, ft^2
S_p	parachute area (laid out flat), ft^2
V	full-scale true rate of descent, fps
X, Y, Z	airplane body axes
x	horizontal distance from leading edge of mean aerodynamic chord to center of gravity, ft
z	vertical distance between center of gravity and fuselage reference line (positive when center of gravity is below fuselage reference line), ft
α	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

δ_a	aileron deflection, deg
δ_e	elevator deflection (positive TE down), deg
δ_r	rudder deflection (positive TE left), deg
μ	relative density of airplane, $m/\rho Sb$
ρ	air density, slugs/ft^3
ϕ	angle between lateral body axis and horizontal, deg
Ω	full-scale period of rotation about spin axis, sec/turn

Abbreviations:

c.g.	center of gravity
FRL	fuselage reference line
FS	fuselage station
IYMP	inertia yawing-moment parameter
TE	trailing edge

Model and Apparatus

A 1/15-scale model of an Australian trainer airplane was furnished by the Australian government and was prepared for testing by the Langley Research Center. A three-view drawing of the basic configuration is shown in figure 1(a) and photographs are shown in figures 1(b) and 1(c). The dimensional characteristics of the airplane are presented in table 1.

The model had two tail configurations: a basic tail and a long tail. The long tail configuration is a modification of the basic configuration in which the vertical tail is moved rearward 15.75 in. full scale (fig. 2). Also included in the investigation were tests to evaluate the effects of strakes, a 20° cutout on the elevator, rudder modifications, and Reynolds number effects by wing leading-edge modifications.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 15 000 ft. The mass characteristics, center-of-gravity position, and inertia parameters for the loadings tested on the model are presented in table 2. Engine effects were not simulated.

A remote-control mechanism was installed in the model to activate the control surfaces for recovery attempts. Sufficient torque was exerted on the control surfaces to reverse them fully and rapidly for the recovery attempts. The airplane has conventional rudder, elevators, and ailerons. Maximum deflection values for each control surface (measured in a plane perpendicular to the hinge line) were as follows:

Control surface	Maximum deflections	
Elevators . . .	25° TE up	23° TE down
Ailerons . . .	23° TE up	13° TE down
Rudder	25° TE right	25° TE left

Model Testing Technique

General descriptions of spin-model testing techniques, methods of interpreting test results, and a correlation between model and airplane results are presented in reference 1.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for a matrix of control settings in various combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder from with the spin to against the spin or by rapid full reversal of both rudder and ailerons. The use of longitudinal control movement for recovery can also be evaluated as required. Tests are conducted for the various possible loading conditions of the airplane because the control manipulation required for recovery is generally dependent on the mass and geometric characteristics of the model.

When investigations are made of modifications to a previously tested model, a greatly reduced matrix of test conditions may be employed. Depending upon the nature of the modifications, only selected critical spins, loadings, and recovery procedures need be assessed.

Turns for recovery are measured from the time that the controls are moved to the time that the spin rotation ceases. Recovery characteristics of a model are generally considered satisfactory if the recovery is obtained within 2 1/4 turns.

For spins in which a model has a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent is recorded as being greater than the velocity at the time that the model hit the safety net (for example, >300 fps full scale). In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast as when the model is in the final steeper attitude.

For recovery attempts in which a model strikes the safety net while it is still in a spin, the recovery is recorded as being greater than the number of turns from the time that the controls were moved to the time that the model struck the net (for example, >3). A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. A recovery in 10 or more turns is indicated by ∞. When a model loses the rotation applied at launch within a few turns and recovers without control movement (rudder and other controls held with the spin), the results are recorded as "no spin."

For spin-recovery parachute tests, the parachute geometry required to effect satisfactory recovery is determined. The parachute is deployed for the recovery attempts by actuating a remotely controlled mechanism, and the controls are maintained prospin so that recovery is due to the parachute action alone.

Test Accuracy

Results determined in free-spinning tunnel tests are believed to be true values within the following limits:

α, deg	1
ϕ, deg	± 1
V, percent	± 5
Ω, percent	± 2
Turns for recovery obtained from motion-picture records	$\pm 1/4$
Turns for recovery obtained visually during test	$\pm 1/2$

All data presented are from motion-picture records unless stated as being from visual observation of a video tape recording. The preceding limits may be exceeded for certain spins in which the model is difficult to control in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of the model is believed to be within the following limits:

Weight, percent	± 1
Center-of-gravity location, percent $\bar{c}$	± 0.3
Moments of inertia, percent	± 5

The controls are set within an accuracy of $\pm 1°$.

Presentation of Results

The results of the model spin tests are presented in charts 1 to 5 and in tables 3 to 18. The data are presented in terms of full-scale values for the airplane at an altitude of 15 000 ft. No power effects were simulated. The model was tested in spins to the right and to the left. The results presented are considered applicable to the airplane for either direction.

Chart 1 presents the footnotes that apply to the charts. In charts 2 to 5, the results for the elevators-up position (stick back) are presented at the top of the charts and the results for the elevators-down position (stick forward) are presented at the bottom of the charts. The results for roll controls with the spin (stick left in a left spin) are presented on the right side of the chart, and the results for the roll controls against the spin (stick right in a left spin) are presented on the left side of the chart. Also presented in the charts and tables is a spin block symbol  that shows at a glance the position of the elevators and ailerons for a given test. The dot on the block symbol indicates the control-surface positions for the developed spin, and the arrowhead gives the position to which the control surfaces were moved for recovery attempts. The rudder was always moved from full with the spin to full against the spin for attempted recoveries unless otherwise indicated.

Results and Discussion

Erect Spin and Recovery Tests

Basic configuration (c.g. = 0.222$\bar{c}$). The test results for the basic configuration with the center of gravity located at 22.2 percent mean aerodynamic chord (loading 1 in table 2) are presented in chart 2. Based on these model test results, the airplane in the basic configuration is expected to spin for all control positions except when the ailerons are deflected full with the spin. The angle of attack of the spin will be about 60°, and the spin period will be about 2.2 seconds per turn. The spin will be 3° or 4° flatter when the ailerons are deflected against the spin.

The effectiveness of the rudder for recovery is strongly influenced by the position of the elevator. For elevators full up (stick back), the recoveries attempted by deflecting the rudder to full against the spin are about 2 turns or less. However, for elevators neutral and down, the recoveries by rudder reversal alone are so poor that rudder reversal alone is judged insufficient to stop the spin. Some improvement in the recovery characteristics can be obtained by deflecting the elevators to neutral or full up and deflecting the ailerons to neutral or full with while moving the rudder to full against the spin. Based on these results, the most effective control input for recovery is rudder full against, elevators full up, and ailerons full with the spin to provide a satisfactory recovery. Any deviation from the optimum recovery controls for this configuration, such as deflecting the elevators only to neutral instead of up (spins 50, 38, and 39 in chart 2) or deflecting the ailerons to neutral instead of full with (spins 49, 54, 37, and 28 in chart 2), indicates considerably degraded recovery characteristics. The need for deflecting the elevators up results from the horizontal tail creating an adverse flow field over the vertical tail. This flow field is improved considerably by deflecting the elevators full up.

Basic configuration with increased rudder length and chord (c.g. = 0.222$\bar{c}$). The basic configuration was modified by increasing the rudder length and chord and adding a small ventral fin (see fig. 3) to improve the recovery characteristics. The results are presented in chart 3 and table 3. These modifications to the rudder made a marked improvement in the recovery characteristics. Satisfactory recovery characteristics were obtained for all conditions by deflecting the rudder to full against the spin and moving the ailerons and elevators to neutral. A direct comparison in the recovery characteristics for the basic and modified rudders is shown in table 3.

In spins 37, 28, and 35, up to 5 turns for recovery were indicated with the basic rudder. However, for the same spins shown with the modified rudder (spins 182, 178, and 179), all recoveries were 2 1/4 turns or less. Even the recoveries by rudder alone for the elevator-down condition (spin 180 in chart 3) were about 3 turns. In contrast, with the basic rudder, no recoveries were obtainable from this spin by rudder alone. The results with the modified rudder show a significant improvement in the recovery characteristics over the basic configuration.

Long tail configuration (c.g. = 0.236$\bar{c}$). The basic configuration was modified by moving the vertical tail rearward and increasing the length of the rudder. (See fig. 2.) The data for this configuration are presented in chart 4 and are compared with the basic configuration in table 4. The modification of moving the vertical tail rearward had a favorable effect on the spin and recovery characteristics. The spin angle of attack for the modified configuration was 10° to 15° steeper (lower angle of attack) than the spin angle of attack for the basic configuration, and the number of turns for recovery was decreased considerably. In table 4, the long tail is compared directly with the basic configuration. Notice that the angle of attack is considerably steeper (44° versus 61°) and the number of turns for recovery vastly improved (1 versus 2 1/2) for the modified configuration with elevators up and ailerons neutral. As would be expected with the spin angle of attack approaching 45°, the spin period also increased. (Compare spin 52 with spin 235 in table 4.) In one spin (spin 230), the recoveries are still marginal because of the 2 3/4-turn recovery.

Long tail configuration with increased rudder chord (c.g. = 0.236$\bar{c}$). The effect of increasing the rudder chord on the long tail configuration is shown in table 5 where the results are compared with the long tail results. A sketch of the increased rudder chord on the long tail is shown in figure 4. As shown in table 5, increasing the rudder chord improved the recovery characteristics to an acceptable level. All recoveries were obtained within 2 turns or less compared with up to 2 3/4 turns for the normal rudder. The spin modes were about the same for the two tail configurations since the angle of attack and spin rate had little or no change. The overall improvement between the long tail with increased rudder chord (table 5) and the basic configuration (chart 2) is considerable. Recoveries of up to 5 turns (spin 28 in chart 2) were obtained on the basic configuration compared with satisfactory recoveries of 2 turns or less on the long tail configuration with increased rudder chord.

Basic configuration with strake 3 and increased rudder length (c.g. = 0.222$\bar{c}$). The effect of increasing the rudder length for the configuration with strake 3 (fig. 5) is shown in table 6. The results for the basic configuration with strake 3, which spins at an angle of attack from 45° to 50°, are compared with the results for the same configuration with increased rudder length. The results show that by increasing the rudder length the recoveries did improve slightly, but they still remained unsatisfactory. The results for the basic rudder indicate that for some cases (spins 89 and 85), recoveries of 3 to greater than 8 turns were obtained. However, even though most recoveries did improve for the conditions where the elevators were down (spin 96), the recoveries were still requiring up to 5 turns. These results also indicate the possibility of an aggravated spin mode, i.e., a spin mode that becomes worse after certain recovery controls are applied (rudder against and stick forward). Rather than recover, the model enters a steep and fast spin and is more difficult to recover.

Effect of c.g. for basic configuration with increased rudder length and chord. The effect of moving the center of gravity forward 5 percent (from 0.222$\bar{c}$ to 0.17$\bar{c}$) is given in table 7. The results indicate that the spin and spin-recovery characteristics would change very little with a forward shift in c.g. As would be expected because of an increase in nose-down pitching moment, the spin rate for the forward c.g. condition is slightly faster and, as a result, the turns for recovery are slightly higher.

Basic configuration with increased rudder length and chord and flaps down (c.g. = 0.17$\bar{c}$). The effect of deflecting the flaps can be seen from table 8. Based on the results of the model with the flaps up and down, it is not expected that deflecting the flaps will have a large influence on the spin and recovery characteristics. There are isolated cases (spins 270 and 285, for example) where it appears that the flaps-down case could cause a steeper spin. However, this result is not consistent with the other spin modes. Therefore, the overall effect of the flaps deflected is expected to be small.

Effect of open canopy. The effect of the open canopy on the spin and recovery characteristics of the model is given in table 9 for the basic configuration with the increased rudder length and chord and for a center of gravity of $0.17\bar{c}$. The results show that the open canopy did not have any effect on the spin and spin-recovery characteristics. Since the spin characteristics are basically the same for the forward center of gravity as for the normal center of gravity, the open canopy is not expected to affect the spin for any loading condition.

Effect of dorsal fin. The effect of the dorsal fin on the erect spin and recovery characteristics is given in table 10 for the long tail configuration. As expected from the results of past tests, the dorsal fin has a negligible effect on the spin and recovery characteristics of the model. The dorsal fin is not expected to influence the spin or recovery for the basic configuration or for any other configurations with similar spin characteristics.

Reynolds number effect. Experience has shown that Reynolds number effects can have an appreciable influence on a spinning model, especially on the wings for a straight wing design that has an airfoil with high leading-edge suction. The Reynolds number was about 1.0×10^6 for the spin-tunnel model and about 4×10^6 for the airplane test. In order to evaluate the possibility of a Reynolds number effect changing the spin modes of the Australian trainer model, a few tests were conducted to determine if Reynolds number could make a difference in the model spin results. As has been done in the past, the model was modified by installing a Krueger-type flap (fig. 6) on the leading edge of the wing so that the model wing in a spin would better simulate the leading-edge-suction characteristics of the full-scale wing. The flap chord was chosen to be 4 percent of the wing chord. Experience and unpublished data have shown that a Krueger flap of this size could make a change in the model spin characteristics and that the results would be more representative of the airplane spin if the leading-edge suction is large enough to influence the airplane spin to a large extent. The leading-edge-suction effect is usually strongest at spin angles of attack from 30° to 45°. The effect diminishes significantly at higher angles of attack, and experience indicates that the effect is negligible at an angle of attack of about 60° and above.

The model results conducted to evaluate the effects of a Krueger flap on the wing leading edge are given in table 11 and compared with model results for the basic wing. The results indicate that simulating a high suction on the wing leading edge did not affect the spin. The spin angle of attack, spin rate, and turns for recovery were about the same for the clean wing as for the modified Krueger-flap wing. These tests with the Krueger-type flap give confidence that the model results will be indicative of the full-scale airplane characteristics.

Effect of improper control movement. The model spin test program was conducted by deflecting the controls to the maximum deflections to evaluate the spin and recovery characteristics. A few tests were conducted by deflecting the controls only to two-thirds their maximum deflection for recovery. The results of these tests for the basic configuration with the longer rudder and increased chord are given in table 12. The 20° elevator cutout is on some but not all model configurations, but the cutout does not influence the results that will be discussed later. The results show that if, for recovery, the elevators are moved to slightly down instead of to neutral (compare spin 182 with 192), or if the ailerons are moved slightly against the spin and the elevators slightly down instead of to neutral (compare spin 189 with 190), the recovery characteristics would be adversely affected, possibly to such an extent that the airplane may not recover.

As was discussed earlier in chart 2, movement of the elevator to the down position is very adverse to recoveries (spins 54, 55, 53, and 14) and could preclude recovery. These results indicate that movement of the elevators down (stick forward) during recovery attempts may possibly cause the airplane to enter an aggravated spin mode rather than recover. The airplane would not be expected to be recoverable in the aggravated spin mode. To obtain recovery, the controls would have to be returned to the normal spin-control configuration (stick back, rudder with, and ailerons neutral), and then the recommended recovery procedure could be used to stop the spin. These results point out the importance of proper control movement for recovery. A slight deflection of the controls in the wrong direction can slow the recovery.

Effect of elevator cutouts. The effect of a 20° elevator cutout (fig. 7) is shown in table 13 for the basic configuration with long rudder and strake 3. The 20° cutout made a slight and insignificant change in spin characteristics, but the recovery characteristics were the same as those without the 20° cutout.

Effect of horizontal strakes. The effects of horizontal strakes on the aft fuselage (fig. 8) were investigated to evaluate the strake effectiveness for improving the spin and recovery characteristics. The results for two of the strake configurations are presented.

The effect of strake 1 is shown in table 14 and was evaluated on the long tail and increased rudder chord configurations. There was no significant change in the spin mode or recovery characteristics because of strake 1.

The effect of strake 3 is shown in table 15 and was evaluated on the basic configuration. The basic configuration had a spin angle of attack of about 60° and recoveries up to 6 turns. With the addition of strake 3, the spin angle of attack decreased to about 45° to 50° but the recoveries improved only slightly; thus, the improvement in recoveries was not considered adequate to provide satisfactory recoveries.

Inverted Spin and Recovery Tests

For inverted spins, the order used for presenting the data on a chart is different from that normally used for erect spins. For inverted spins, data for the ailerons with the spin condition (controls crossed, that is, left rudder pedal forward and stick to the pilot's right for a spin yawing to the pilot's left and rolling to his right) are presented on the right side of the chart; data for the ailerons against the spin condition (controls together, that is, left rudder pedal forward and stick to the pilot's left for a spin yawing to the pilot's left) are presented on the left side of the chart. When the controls are crossed in an inverted spin, the ailerons aid the rolling motion; when the controls are together, the ailerons oppose the rolling motion. The angle of wing tilt in the chart is given as up (U) or down (D) relative to the ground. The elevator up or down deflection is also given in relation to the ground; therefore, the results for elevators up (stick forward) are presented at the top of the chart and for elevators down (stick back) at the bottom of the chart.

Inverted spin tests were conducted on the following configurations: (1) the basic configuration with the rudder length and chord increased and with the 20° elevator cutout for the normal ($0.222\bar{c}$) and rearward center-of-gravity positions, and (2) the long tail configurations with the center of gravity at the normal ($0.236\bar{c}$) position. The results are presented in table 16. Based on these tests, it is expected that an inverted spin will be obtained only for the prospin control position (stick forward, rudder with, and ailerons with). The angle of attack of the spin is about $-35°$ to $-55°$, roll oscillations are about 0° to 20° (inner wing down), and the model rotates at about 2.2 to 2.9 seconds per turn. Recovery from the spin will be rapid by rudder reversal and neutralizing the elevators and ailerons. Although an inverted spin is not expected for most other control positions, if an inverted spin does occur, it is predicted to be very steep. Inverted spins for the long tail configuration will be similar to those of the basic configuration except somewhat steeper (more nose down).

The recommended control technique for recovery from all inverted spins is deflecting the rudder against the spin and the elevators and ailerons to neutral.

Spin-Recovery Parachute Tests

The results of the model tests to determine the parachute size required to provide emergency spin recoveries for the airplane are presented in table 17 for the erect spins and in table 18 for the inverted spins. The parachute diameter given in the tables is the full-scale laid-out-flat diameter, and the drag coefficient (0.5) is based on the laid-out-flat diameter. The length of the shroud lines is equal to the parachute diameter. The distance ℓ listed in tables 17 and 18 is the distance from the parachute attachment point to the parachute canopy (equal to the riser length plus the shroud line length).

Based on all the parachute test results for the erect spins, it has been determined that emergency spin recovery can be obtained on the airplane (with prospin controls maintained) from erect spins by deploying a parachute 11.3 ft in diameter with a line length of 25 ft (the distance from the attachment point to the canopy).

Based on the test results for the inverted spin, the 11.3-ft-diameter parachute will not recover the airplane with the prospin rudder deflected. A parachute as large as 15.7 ft in diameter would be required to provide recoveries from inverted spins with the prospin rudder deflected. However, good recoveries can be obtained with the 11.3-ft parachute if the rudder is moved to neutral in combination with the parachute deployment.

Summary of Results

An investigation was conducted in the Langley Spin Tunnel to determine the spin and recovery characteristics of a 1/15-scale model of an Australian trainer airplane and the effects of various modifications to the tail. Model tests indicate the following results:

1. The basic configuration will spin erect at an angle of attack of about 63° at about 2 to 2.3 seconds per turn. Recovery from this spin was unsatisfactory by rudder reversal or by rudder reversal and ailerons deflected to full with the spin.

2. The elevators had a pronounced effect on the recovery characteristics. The elevators-down position was very adverse to recoveries, whereas the elevators-up position was very favorable to recoveries.

3. The ailerons were prospin when deflected against the spin and were antispin when deflected with the spin.

4. A 7½-in. (full-scale) extension to the chord and length of the basic configuration rudder made a significant improvement in the spin and recovery characteristics. Satisfactory recoveries were obtained by deflecting the rudder to full against the spin and the elevator and ailerons to neutral.

5. The long tail configuration (vertical tail on basic configuration moved rearward 15.75 in.) spun 10° to 15° steeper than the basic configuration and the recoveries were faster. However, the recoveries with the rudder full against the spin and the elevators deflected to neutral were marginal in some cases.

6. Moving the center of gravity forward had little or no effect on the developed spin and recovery characteristics.

7. Improper control movement for recovery can cause a slow recovery or may preclude recovery altogether. Reversing the rudder to less than full against the spin or deflecting the elevators to partly down instead of to neutral will be very adverse to recoveries.

8. Inverted spins were obtained for only the prospin control configuration (that is, rudder with the spin, stick forward, and ailerons deflected to roll in the opposite direction to the spin). The spin angle of attack was about −35° to −55°, roll oscillations were about 0° to 20° (inner wing down), and the model rotated at 2.2 to 2.9 seconds per turn.

9. Recovery from all inverted spins was rapid by deflecting the rudder to full against the spin and moving the ailerons and elevators to neutral.

10. The parachute size recommended for emergency spin recovery for all erect spins on the airplane is 11.3 ft in diameter with a line length of 25 ft (the distance from the attachment point to the canopy) and having a drag coefficient of 0.5 (based on the laid-out-flat diameter). The 11.3-ft-diameter parachute will provide recoveries from all inverted spins provided the rudder is deflected to neutral at the time that the parachute is deployed.

11. Model test results indicated that the dorsal fin, strakes, open canopy, and 20° elevator cutouts would have no effect on the spin and spin-recovery characteristics.

12. Tests made to determine if the large Reynolds number difference between the wing of the model and airplane could cause a significant change in the spin indicated that the model results should be representative of the airplane spin and recovery characteristics.

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February 11, 1987

Reference

1. Neihouse, Anshal I.; Klinar, Walter J.; and Scher, Stanley H.: *Status of Spin Research for Recent Airplane Designs.* NASA TR-57, 1960. (Supersedes NACA RM L57F12.)

Table 1. Dimensional Characteristics of Australian Trainer Airplane

[Dimensions are full scale]

Overall length, ft	33.04
Wing:	
Span, ft	36.09
Root chord, in.	95.43
Tip chord, in.	47.72
Area, sq ft	215.25
Mean aerodynamic chord, in.	74.21
Aspect ratio	6.0
Dihedral, deg	7.0
Incidence:	
Root, deg	3.0
Tip, deg	3.0
Airfoil section:	
Root	NACA 23018
Tip	NACA 23012
Horizontal tail:	
Span, ft	14.76
Incidence, deg	0
Airfoil section	NACA 0012
Area, sq ft	83.87
Vertical tail:	
Airfoil section	NACA 0012
Area, sq ft	44.6

Table 2. Mass Characteristics and Inertia Parameters for Loadings Tested on 1/15-Scale Model of Australian Trainer

[Values given are full scale; moments of inertia are given about the c.g.]

Loading		Weight,	Center-of-gravity location		Relative density, μ, at —		Moments of inertia, slug-ft^2			Mass parameters		
No.	Condition	lb	$x/\bar{c}$	$z/\bar{c}$	Sea level	15 000 ft	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1	Basic; normal c.g.	4520	0.222	0.098	7.60	12.08	2111	5407	7052	-180×10^{-4}	-90×10^{-4}	270×10^{-4}
2	Basic; aft c.g.	4528	.294	.095	7.61	12.10	2188	5793	7574	−197	−97	294
3	Long tail; normal c.g.	4528	.236	.104	7.61	12.10	2201	5065	6849	−156	−97	253
4	Basic; forward c.g.	4330	.17	.084	7.28	11.57	2196	4655	6370	−140	−98	238

TABLE 3.- EFFECT OF LONG RUDDER AND INCREASED CHORD

$[(I_X - I_Y)/mb^2 = -180 \times 10^{-4};\ \ c.g. = 0.222\bar{c}]$

u - up   W - with   U - inner wing up
d - down   A - against   D - inner wing down

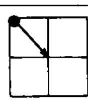
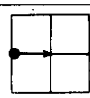
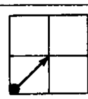
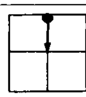
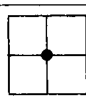
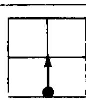
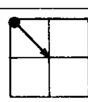
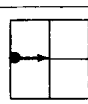
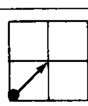
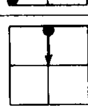
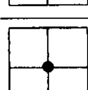
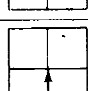
Spin no.	Spin block	Spin characteristics				Control deflection, deg For spin For recovery			Turns for recovery
		α, deg	V, fps	ϕ, deg	Ω, sec/turn	δ_r	δ_e	δ_a	
Basic configuration									
49		63	144	0	2.3	25W 25A	25u 0	L13d R23u 0	$2\frac{3}{4}$, $2\frac{3}{4}$
37		64	139	7U 2D	2.0	25W 25A	0 0	L13d R23u 0	$4\frac{1}{2}$, $4\frac{1}{2}$
28		63	136	7U 5D	2.0	25W 25A	23d 0	L13d R23u 0	5, $5\frac{1}{4}$
52		61	144	3U 7D	2.3	25W 25A	25u 0	0 0	$2\frac{1}{4}$, $2\frac{1}{2}$
15		59	139	4U 5D	2.2	25W 25A	0 0	0 0	2, $3\frac{3}{4}$, 4
35		61	136	5U 6D	2.1	25W 25A	23d 0	0 0	4, $4\frac{1}{4}$
Basic plus long rudder and increased chord									
183		62	141	5U 1D	2.6	25W 25A	25u 0	L13d R23u 0	1, 1, $1\frac{3}{4}$
182		63	141	4U 4D	2.2	25W 25A	0 0	L13d R23u 0	$2\frac{1}{4}$, $2\frac{1}{4}$
178		65	144	2U 4D	2.1	25W 25A	23d 0	L13d R23u 0	$1\frac{3}{4}$, 2
184		48	179	2U 10D	2.9	25W 25A	25u 0	0 0	$\frac{1}{2}$, $\frac{1}{2}$
181		58	141	5U 2D	2.3	25W 25A	0 0	0 0	$1\frac{1}{4}$, $1\frac{1}{2}$
179		60	141	2U	2.2	25W 25A	23d 0	0 0	$1\frac{1}{2}$, $1\frac{3}{4}$

TABLE 4.- EFFECT OF MOVING VERTICAL TAIL REARWARD

$[(I_X - I_Y)/mb^2 = -180 \times 10^{-4}; \quad \text{c.g.} = 0.222\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

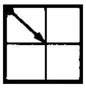
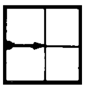
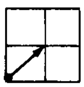
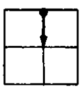
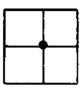
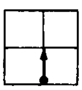
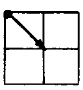
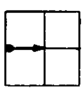
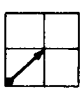
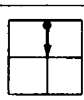
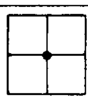
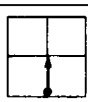
Spin no.	Spin block	Spin characteristics: α, deg	Spin characteristics: V, fps	Spin characteristics: φ, deg	Spin characteristics: Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	Control deflection, deg (For spin / For recovery): δ_e	Control deflection, deg (For spin / For recovery): δ_a	Turns for recovery
Basic configuration									
49		63	144	0	2.3	25W / 25A	25u / 0	L13d R23u / 0	$2\frac{3}{4}$, $2\frac{3}{4}$
37		64	139	7U 2D	2.0	25W / 25A	0 / 0	L13d R23u / 0	$4\frac{1}{2}$, $4\frac{1}{2}$
28		63	136	7U 5D	2.0	25W / 25A	23d / 0	L13d R23u / 0	5, $5\frac{1}{4}$
52		61	144	3U 7D	2.3	25W / 25A	25u / 0	0 / 0	$2\frac{1}{4}$, $2\frac{1}{2}$
15		59	139	4U 5D	2.2	25W / 25A	0 / 0	0 / 0	2, $3\frac{3}{4}$, 4
35		61	136	5U 6D	2.1	25W / 25A	23d / 0	0 / 0	4, $4\frac{1}{4}$
Long tail configuration									
234		48	165	6U 3D	2.6	25W / 25A	25u / 0	L13d R23u / 0	1, $1\frac{1}{4}$
233		57	141	2U	2.1	25W / 25A	0 / 0	L13d R23u / 0	2, $2\frac{1}{2}$, $2\frac{1}{2}$
230			139		2.1	25W / 25A	23d / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{3}{4}$
235		44	179	3U 6D	2.6	25W / 25A	25u / 0	0 / 0	1
236		41	160	6U 0	1.9	25W / 25A	0 / 0	0 / 0	$1\frac{1}{4}$
231		53	146	1D	2.0	25W / 25A	23d / 0	0 / 0	2, $2\frac{1}{4}$

TABLE 5.- EFFECT OF INCREASED RUDDER CHORD ON LONG TAIL

$[(I_X - I_Y)/mb^2 = -156 \times 10^{-4}; \quad c.g. = 0.236\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

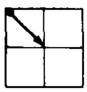
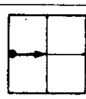
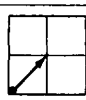
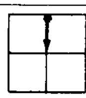
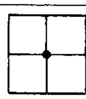
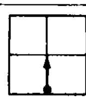
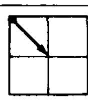
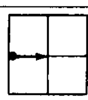
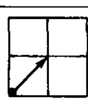
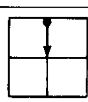
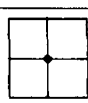
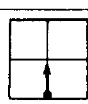
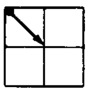
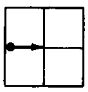
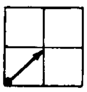
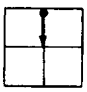
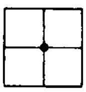
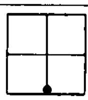
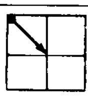
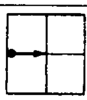
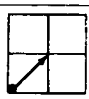
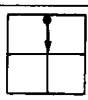
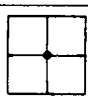
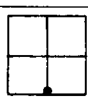
Spin no.	Spin block	Spin characteristics: α, deg	V, fps	ϕ, deg	Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	Turns for recovery
Long tail configuration									
234		48	165	6U 3D	2.6	25W / 25A	25u / 0	L13d R23u / 0	1, $1\frac{1}{4}$
233		57	141	2U	2.1	25W / 25A	0 / 0	L13d R23u / 0	2, $2\frac{1}{2}$, $2\frac{1}{2}$
230			139		2.1	25W / 25A	23d / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{3}{4}$
235		44	179	3U 6D	2.6	25W / 25A	25u / 0	0 / 0	1
236		41	160	6U 0	1.9	25W / 25A	0 / 0	0 / 0	$1\frac{1}{4}$
231		53	146	1D	2.0	25W / 25A	23d / 0	0 / 0	2, $2\frac{1}{4}$
Long tail plus increased rudder chord									
253		49	157	8U 0	2.6	25W / 25A	25u / 0	L13d R23u / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
248		51	141	6U 0	2.0	25W / 25A	0 / 0	L13d R23u / 0	$1\frac{3}{4}$, 2, 2
247		55	136	3U	1.9	25W / 25A	23d / 0	L13d R23u / 0	$1\frac{3}{4}$, 2, 2
251		46	163	1D 7D	2.7	25W / 25A	25u / 0	0 / 0	1, 1
250		43	146	5U 3D	2.0	25W / 25A	0 / 0	0 / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
249		46	141	0	1.9	25W / 25A	23d / 0	0 / 0	$1\frac{1}{2}$, $1\frac{1}{2}$

TABLE 6.- EFFECT OF LONG RUDDER ON BASIC CONFIGURATION WITH STRAKE 3

$[(I_X - I_Y)/mb^2 = -180 \times 10^{-4}; \quad \text{c.g.} = 0.222\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

Spin no.	Spin block	Spin characteristics: α, deg	V, fps	ϕ, deg	Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	Turns for recovery
Basic plus strake 3									
90		48	176	2U	2.8	25W / 25A	25u / 0	L13d R23u / 0	[a]$1\frac{1}{2}$, [a]$1\frac{1}{2}$, [a]$1\frac{1}{2}$
92		51	157	9U 4D	2.3	25W / 25A	0 / 0	L13d R23u / 0	2, $2\frac{1}{2}$
89		57	139	2U	2.2	25W / 25A	23d / 0	L13d R23u / 0	$3\frac{1}{4}$, [a]$3\frac{1}{2}$
91		45	179	5D	2.7	25W / 25A	25u / 0	0 / 0	[a]$1\frac{1}{2}$, [a]$1\frac{1}{2}$
84		38	185	4U 2D	2.2	25W / 25A	0 / 0	0 / 0	$1\frac{1}{2}$, [a]$1\frac{1}{2}$
85		45	185	6U 4D	2.0	25W / 25A	23d / 23d	0 / 0	>[a]7, >[a]8
Basic plus strake 3 and long rudder									
102		44	187	6U 1D	2.8	25W / 25A	25u / 0	L13d R23u / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
103		48	160	15U 5D	2.3	25W / 25A	0 / 0	L13d R23u / 0	$1\frac{1}{2}$, [a]2, [a]2
104		48 60	149	12U 5D	2.2	25W / 25A	23d / 0	L13d R23u / 0	2, $2\frac{1}{4}$, $2\frac{1}{4}$
101		51	174	4D	2.7	25W / 25A	25u / 0	0 / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
97		Very steep spin				25W / 25A	0 / 0	0 / 0	$1\frac{1}{2}$
96		Very steep spin				25W / 25A	23d / 23d	0 / 0	[a]3, [a]3, [a]5

[a]From visual observation.

TABLE 7.- EFFECT OF FORWARD CENTER OF GRAVITY ON BASIC CONFIGURATION WITH LONG RUDDER AND INCREASED CHORD

u - up d - down W - with A - against U - inner wing up D - inner wing down

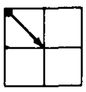
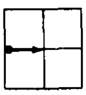
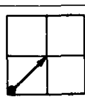
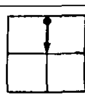
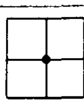
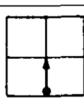
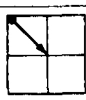
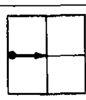
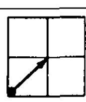
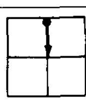
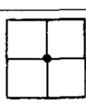
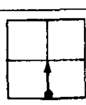
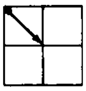
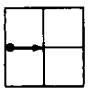
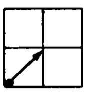
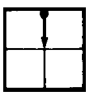
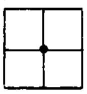
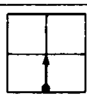
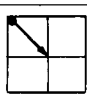
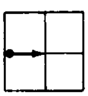
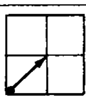
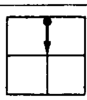
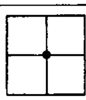
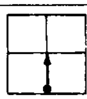
Spin no.	Spin block	Spin characteristics: α, deg	V, fps	φ, deg	Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	Turns for recovery
c.g. = 0.222$\bar{c}$; $(I_X - I_Y)/mb^2 = -180 \times 10^{-4}$									
183		62	141	5U 1D	2.6	25W / 25A	25u / 0	L13d R23u / 0	1, 1, $1\frac{3}{4}$
182		63	141	4U 4D	2.2	25W / 25A	0 / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{4}$
178		65	144	2U 4D	2.1	25W / 25A	23d / 0	L13d R23u / 0	$1\frac{3}{4}$, 2
184		48	179	2U 10D	2.9	25W / 25A	25u / 0	0 / 0	$\frac{1}{2}$, $\frac{1}{2}$
181		58	141	5U 2D	2.3	25W / 25A	0 / 0	0 / 0	$1\frac{1}{4}$, $1\frac{1}{2}$
179		60	141	2U	2.2	25W / 25A	23d / 0	0 / 0	$1\frac{1}{2}$, $1\frac{3}{4}$
c.g. = 0.17$\bar{c}$; $(I_X - I_Y)/mb^2 = -140 \times 10^{-4}$									
270		59	141	3U 4D	2.2	25W / 25A	25u / 0	L13d R23u / 0	2, 2
271		60	133	1U	1.9	25W / 25A	0 / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{4}$
272		61	131	5U 2D	1.9	25W / 25A	23d / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{1}{2}$
268		45	168	2D	2.5	25W / 25A	25u / 0	0 / 0	$1\frac{1}{4}$
274		42	157	2U	2.0	25W / 25A	0 / 0	0 / 0	$\frac{3}{4}$, $1\frac{3}{4}$, 2
273		56	133	1D	2.0	25W / 25A	23d / 0	0 / 0	$1\frac{7}{8}$, 2

TABLE 8.- EFFECT OF WING FLAPS ON BASIC CONFIGURATION WITH LONG RUDDER AND INCREASED RUDDER CHORD

$[(I_X - I_Y)/mb^2 = -140 \times 10^{-4};\ \text{c.g.} = 0.17\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

Spin no.	Spin block	Spin characteristics				Control deflection, deg (For spin / For recovery)			Turns for recovery
		α, deg	V, fps	ϕ, deg	Ω, sec/turn	δ_r	δ_e	δ_a	
Basic plus long rudder and increased chord									
270		59	141	3U 4D	2.2	25W / 25A	25u / 0	L13d R23u / 0	2, 2
271		60	133	1U	1.9	25W / 25A	0 / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{4}$
272		61	131	5U 2D	1.9	25W / 25A	23d / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{1}{2}$
268		45	168	2D	2.5	25W / 25A	25u / 0	0 / 0	$1\frac{1}{4}$
274		42	157	2U	2.0	25W / 25A	0 / 0	0 / 0	$\frac{3}{4}$, $1\frac{3}{4}$, 2
273		56	133	1D	2.0	25W / 25A	23d / 0	0 / 0	$1\frac{7}{8}$, 2
Basic plus long rudder and increased chord and flaps down									
285		46	157	7U 1D	2.5	25W / 25A	25u / 0	L13d R23u / 0	[a]1, [a]$1\frac{1}{4}$, [a]$1\frac{1}{4}$
284		58	141	1U	2.0	25W / 25A	0 / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{2}$
281		56	136	1U	1.9	25W / 25A	23d / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{4}$
286		Very steep and whipping spin				25W / 25A	25u / 0	0 / 0	$\frac{1}{2}$, 1
288		49	136	1D	2.0	25W / 25A	0 / 0	0 / 0	$2\frac{1}{2}$, $2\frac{1}{2}$
282		53	131	1D	2.0	25W / 25A	23d / 0	0 / 0	2, 2, 2

[a]From visual observation.

TABLE 9.- EFFECT OF OPEN CANOPY ON BASIC CONFIGURATION WITH LONG RUDDER AND INCREASED RUDDER CHORD

$[(I_X - I_Y)/mb^2 = -140 \times 10^{-4}; \quad \text{c.g.} = 0.17\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

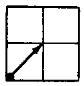
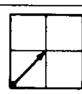
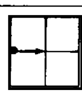
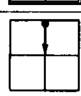
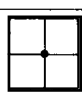
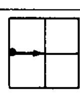
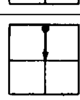
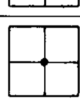
Spin no.	Spin block	Spin characteristics: α, deg	V, fps	φ, deg	Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	Turns for recovery
Closed canopy									
272		61	131	5U 2D	1.9	25W / 25A	23d / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{1}{2}$
Open canopy									
277		63	136	2U	1.9	25W / 25A	23d / 0	L13d R23u / 0	2, $2\frac{1}{4}$, $2\frac{1}{4}$

TABLE 10.- EFFECT OF DORSAL FIN ON LONG TAIL CONFIGURATION

$[(I_X - I_Y)/mb^2 = -156 \times 10^{-4}; \quad \text{c.g.} = 0.236\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

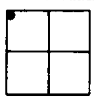
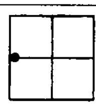
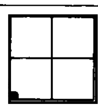
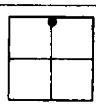
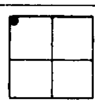
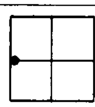
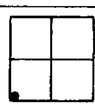
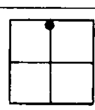
Spin no.	Spin block	Spin characteristics: α, deg	V, fps	φ, deg	Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	Turns for recovery
Long tail configuration									
233		57	141	2U	2.1	25W / 25A	0 / 0	L13d R23u / 0	2, $2\frac{1}{2}$, $2\frac{1}{2}$
235		44	179	3U 6D	2.6	25W / 25A	25u / 0	0 / 0	[a]1
236		41	160	6U 0	1.9	25W / 25A	0 / 0	0 / 0	[a]$1\frac{1}{4}$
Long tail with dorsal fin removed									
264		54	136	3U	1.9	25W / 25A	0 / 0	L13d R23u / 0	$2\frac{1}{4}$, [a]$2\frac{1}{4}$
265		46	163	2D	2.3	25W / 25A	25u / 0	0 / 0	1, 1
263		41	163	4U 3D	1.9	25W / 25A	0 / 0	0 / 0	$1\frac{1}{4}$, $1\frac{1}{4}$

[a]From visual observation.

TABLE 11.- EFFECT OF KRUEGER FLAPS ON BASIC CONFIGURATION
WITH LONG RUDDER AND STRAKE 3

$[(I_X - I_Y)/mb^2 = -180 \times 10^{-4}; \quad \text{c.g.} = 0.222\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

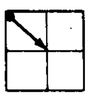
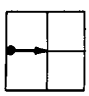
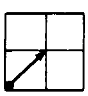
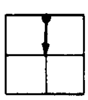
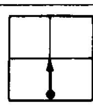
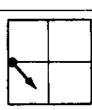
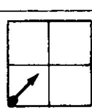
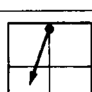
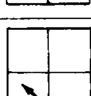
Spin no.	Spin block	Spin characteristics: α, deg	Spin characteristics: V, fps	Spin characteristics: ϕ, deg	Spin characteristics: Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	Control deflection, deg (For spin / For recovery): δ_e	Control deflection, deg (For spin / For recovery): δ_a	Turns for recovery
Basic plus long rudder and strake 3									
99		44	187	6U 1D	2.8	25W / 25A	25u / 25u	L13d R23u / L13d R23u	$\frac{1}{4}$, [a]$\frac{3}{4}$
98		48	160	15U 5D	2.3	25W / 25A	0 / 0	L13d R23u / L13d R23u	$1\frac{3}{4}$, 2, 2
95		48 60	149	12U 5D	2.2	25W / 25A	23d / 23d	L13d R23u / L13d R23u	[a]4, [a]$4\frac{1}{2}$, $4\frac{1}{2}$
100		51	174	4D	2.7	25W / 25A	25u / 25u	0 / 0	[a]$\frac{1}{2}$, 1
Basic plus long rudder, strake 3, and 4-percent Krueger flaps									
106		46	179	3U	2.9	25W / 25A	25u / 25u	L13d R23u / L13d R23u	$\frac{3}{4}$, $\frac{3}{4}$
111		56	152	5U 2D	2.3	25W / 25A	0 / 0	L13d R23u / L13d R23u	$1\frac{1}{2}$, $2\frac{1}{4}$
110		56	152	9U 5D	2.2	25W / 25A	23d / 23d	L13d R23u / L13d R23u	$3\frac{1}{2}$, $3\frac{1}{2}$
107		50	174	2D 9D	2.9	25W / 25A	25u / 25u	0 / 0	[a]$\frac{1}{2}$, $\frac{3}{4}$

[a]From visual observation.

TABLE 12.- EFFECT OF IMPROPER CONTROL MOVEMENT FOR RECOVERY

u - up W - with U - inner wing up
d - down A - against D - inner wing down

(a) $(I_X - I_Y)/mb^2 = -156 \times 10^{-4}$; c.g. = $0.236\bar{c}$

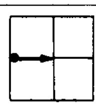
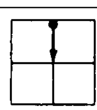
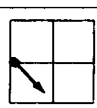
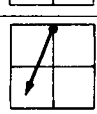
Spin no.	Spin block	Spin characteristics: α, deg	V, fps	φ, deg	Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	Turns for recovery
Long tail configuration - proper control input									
234		48	165	6U 3D	2.6	25W / 25A	25u / 0	L13d R23u / 0	$1, 1\frac{1}{4}$
233		57	141	2U	2.1	25W / 25A	0 / 0	L13d R23u / 0	$2, 2\frac{1}{2}, 2\frac{1}{2}$
230			139		2.1	25W / 25A	23d / 0	L13d R23u / 0	$2\frac{1}{4}, 2\frac{3}{4}$
235		44	179	3U 6D	2.6	25W / 25A	25u / 0	0 / 0	[a]1
231		53	146	1D	2.0	25W / 25A	23d / 0	0 / 0	$2, 2\frac{1}{4}$
Long tail configuration - improper control input									
238		48	165	6U 3D	2.6	25W / 17A	25u / 8d	L13d R23u / L4d R8u	3, 3
239		57	141	2U	2.1	25W / 17A	0 / 8d	L13d R23u / L4d R8u	$5\frac{3}{4}$
240			139		2.1	25W / 17A	23d / 8d	L13d R23u / L4d R8u	$5\frac{1}{2}$
242		44	179	3U 6D	2.6	25W / 17A	25u / 8d	0 / L4d R8u	$1\frac{3}{4}, 2\frac{1}{4}$
241		53	146	1D	2.0	25W / 17A	23d / 8d	0 / L4d R8u	$4\frac{1}{2}, 4\frac{1}{2}$

[a]From visual observation.

TABLE 12.- Concluded

u - up   W - with   U - inner wing up
d - down   A - against   D - inner wing down

(b) $(I_X - I_Y)/mb^2 = -180 \times 10^{-4}$; c.g. = $0.229\bar{c}$

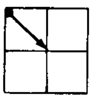
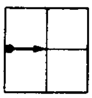
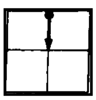
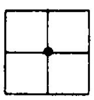
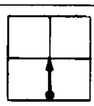
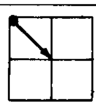
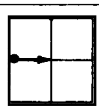
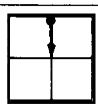
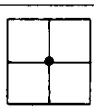
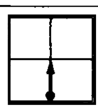
Spin no.	Spin block	Spin characteristics				Control deflection, deg (For spin / For recovery)			Turns for recovery
		α, deg	V, fps	ϕ, deg	Ω, sec/turn	δ_r	δ_e	δ_a	
Basic plus long rudder and increased chord									
182		63	141	4U 4D	2.2	25W / 25A	0 / 0	L13d R23u / 0	$2\frac{1}{4}$, $2\frac{1}{4}$
189		53	163	4D	2.9	25W / 25A	25u / 0	0 / 0	[a]1, [a]1
Basic plus long rudder and increased chord; 20° cutout									
192		64	125	7U 5D	2.1	25W / 17A	0 / 8d	L13d R23u / L4d R8u	$4\frac{3}{4}$, 6
190		53	163	4D	2.9	25W / 25A	25u / 8d	0 / L4d R8u	$1\frac{1}{4}$, 2, $2\frac{1}{4}$

[a]Also has 20° elevator cutout.

TABLE 13.- EFFECT OF 20° ELEVATOR CUTOUT

$[(I_X - I_Y)/mb^2 = -180 \times 10^{-4}; \quad \text{c.g.} = 0.222\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

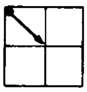
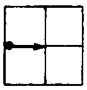
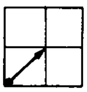
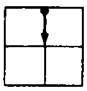
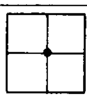
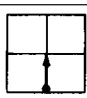
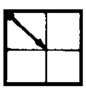
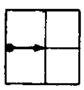
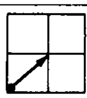
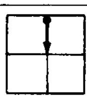
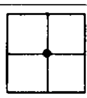
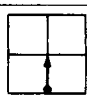
Spin no.	Spin block	Spin characteristics				Control deflection, deg (For spin / For recovery)			Turns for recovery
		α, deg	V, fps	ϕ, deg	Ω, sec/turn	δ_r	δ_e	δ_a	
Basic plus strake 3 and long rudder									
102		44	187	6U 1D	2.8	25W / 25A	25u / 0	L13d R23u / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
103		48	160	15U 5D	2.3	25W / 25A	0 / 0	L13d R23u / 0	$1\frac{1}{2}$, 2, 2
101		51	174	4D	2.7	25W / 25A	25u / 0	0 / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
97		Very steep spin				25W / 25A	0 / 0	0 / 0	$1\frac{1}{2}$
105		Very steep spin				25W / 25A	23d / 0	0 / 0	$1\frac{1}{2}$, 2
Basic plus strake 3, long rudder, and 20° elevator cutout									
157		51	168	0 6D	2.8	25W / 25A	25u / 0	L13d R23u / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
158		49 62	157	9U 13D	2.4	25W / 25A	0 / 0	L13d R23u / 0	[a] $1\frac{1}{2}$, $1\frac{3}{4}$
156		52	160	8U 2U	2.9	25W / 25A	25u / 0	0 / 0	$1\frac{1}{4}$, $1\frac{1}{2}$
161		47	157	3U 3D	2.3	25W / 25A	0 / 0	0 / 0	$1\frac{1}{2}$, $1\frac{3}{4}$
160		44	163	2U 4D	2.2	25W / 25A	23d / 0	0 / 0	$1\frac{1}{2}$, $1\frac{3}{4}$

[a] From visual observation.

TABLE 14.- EFFECT OF STRAKE 1 ON LONG TAIL CONFIGURATION

$\left[(I_X - I_Y)/mb^2 = -156 \times 10^{-4};\ \ \text{c.g.} = 0.236\bar{c}\right]$

u - up   W - with   U - inner wing up
d - down   A - against   D - inner wing down

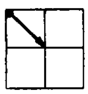
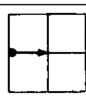
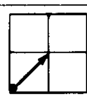
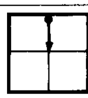
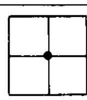
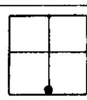
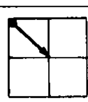
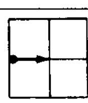
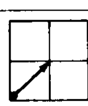
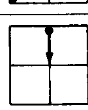
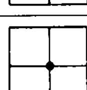
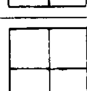
Spin no.	Spin block	Spin characteristics: α, deg	V, fps	φ, deg	Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	Turns for recovery
Long tail plus increased rudder chord									
253		49	157	8U 0	2.6	25W / 25A	25u / 0	L13d R23u / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
248		51	141	6U 0	2.0	25W / 25A	0 / 0	L13d R23u / 0	$1\frac{3}{4}$, 2, 2
247		55	136	3U	1.9	25W / 25A	23d / 0	L13d R23u / 0	$1\frac{3}{4}$, 2, 2
251		46	163	1D 7D	2.7	25W / 25A	25u / 0	0 / 0	1, 1
250		43	146	5U 3D	2.0	25W / 25A	0 / 0	0 / 0	$1\frac{1}{4}$, $1\frac{1}{4}$
249		46	141	0	1.9	25W / 25A	23d / 0	0 / 0	$1\frac{1}{2}$, $1\frac{1}{2}$
Long tail plus increased rudder chord and strake 1									
259		50	149	7U 0	2.3	25W / 25A	25u / 0	L13d R23u / 0	$1\frac{3}{4}$, $1\frac{3}{4}$
256		51	141	4U	2.0	25W / 25A	0 / 0	L13d R23u / 0	$1\frac{3}{4}$, $1\frac{3}{4}$
255		53	136	3U	1.9	25W / 25A	23d / 0	L13d R23u / 0	$2\frac{1}{4}$, [a]$2\frac{1}{4}$
258		45	168	2U 7D	2.3	25W / 25A	25u / 0	0 / 0	$\frac{3}{4}$, 1
257		36	179	5U 1D	1.9	25W / 25A	0 / 0	0 / 0	$1\frac{1}{4}$, [a]$1\frac{1}{2}$
260		35	157	3U	1.7	25W / 25A	23d / 0	0 / 0	1, $1\frac{1}{4}$

[a]From visual observation.

TABLE 15.- EFFECT OF STRAKE 3 ON BASIC CONFIGURATION

$[(I_X - I_Y)/mb^2 = -180 \times 10^{-4};\ \text{c.g.} = 0.222\bar{c}]$

u - up W - with U - inner wing up
d - down A - against D - inner wing down

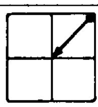
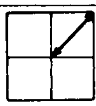
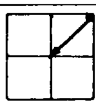
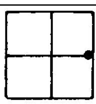
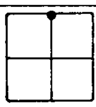
Spin no.	Spin block	Spin characteristics: α, deg	V, fps	φ, deg	Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	δ_e	δ_a	Turns for recovery
Basic configuration									
49		63	144	0	2.3	25W / 25A	25u / 0	L13d R23u / 0	$2\frac{3}{4}$, $2\frac{3}{4}$
37		64	139	7U 2D	2.0	25W / 25A	0 / 0	L13d R23u / 0	$4\frac{1}{2}$, $4\frac{1}{2}$
28		63	136	7U 5D	2.0	25W / 25A	23d / 0	L13d R23u / 0	5, $5\frac{1}{4}$
52		61	144	3U 7D	2.3	25W / 25A	25u / 0	0 / 0	$2\frac{1}{4}$, $2\frac{1}{2}$
15		59	139	4U 5D	2.2	25W / 25A	0 / 0	0 / 0	2, $3\frac{3}{4}$, 4
14		61	136	5U 6D	2.1	25W / 25A	23d / 23d	0 / 0	∞
Basic plus strake 3									
90		48	176	2U	2.8	25W / 25A	25u / 0	L13d R23u / 0	[a]$1\frac{1}{2}$, [a]$1\frac{1}{2}$, [a]$1\frac{1}{2}$
92		51	157	9U 4D	2.3	25W / 25A	0 / 0	L13d R23u / 0	2, $2\frac{1}{2}$
89		57	139	2U	2.2	25W / 25A	23d / 0	L13d R23u / 0	$3\frac{1}{4}$, [a]$3\frac{1}{2}$
91		45	179	5D	2.7	25W / 25A	25u / 0	0 / 0	$1\frac{1}{2}$, [a]$1\frac{1}{2}$
84		38	185	4U 2D	2.2	25W / 25A	0 / 0	0 / 0	$1\frac{1}{2}$, [a]$1\frac{1}{2}$
85		45	185	6U 4D	2.0	25W / 25A	23d / 23d	0 / 0	>[a]7, >[a]8

[a]From visual observation.

TABLE 16.- RESULTS OF INVERTED SPIN AND RECOVERY TEST

[Model configurations as indicated; spin direction to pilot's right; elevator down (stick forward)]

R - right u - up U - inner wing up
L - left d - down D - inner wing down

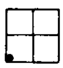
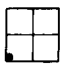
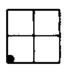
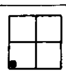
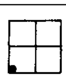
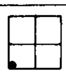
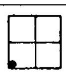
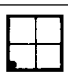
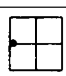
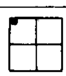
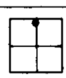
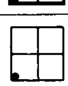
Spin no.	Spin block	Spin characteristics: α, deg	Spin characteristics: V, fps	Spin characteristics: ϕ, deg	Spin characteristics: Ω, sec/turn	Control deflection, deg (For spin / For recovery): δ_r	Control deflection, deg (For spin / For recovery): δ_e	Control deflection, deg (For spin / For recovery): δ_a	Turns for recovery
Basic plus increased rudder length and chord plus 20° elevator cutout; c.g. = 0.222$\bar{c}$; $(I_X - I_Y)/mb^2$ = -180 × 10^{-4}									
211		-56 -32	168	0 23D	2.7	25R / 25L	23d / 0	L13d R23u / 0	[a]$\frac{1}{2}$, [a]$\frac{1}{2}$
Basic plus increased rudder length and chord plus 20° elevator cutout; c.g. = 0.294$\bar{c}$; $(I_X - I_Y)/mb^2$ = -197 × 10^{-4}									
225		-56 -37	174	2U 21D	2.9	25R / 25L	23d / 0	L13d R23u / 0	[a]$\frac{1}{2}$, [a]$\frac{1}{2}$
Long tail; c.g. = 0.236$\bar{c}$; $(I_X - I_Y)/mb^2$ = -156 × 10^{-4}									
244		-44 -33	193	2D 19D	2.2	25R / 25L	23d / 0	L13d R23u / 0	[a]$\frac{1}{4}$, [a]$\frac{1}{4}$
245		No spin							
246		Very steep							

[a]Recovery attempted by deflecting rudder to full against spin and ailerons and elevators to neutral.

TABLE 17.- RESULTS OF SPIN-RECOVERY PARACHUTE TESTS FOR ERECT SPINS

[Basic configuration unless otherwise noted; weight, 4520 lb; c.g. = 0.222$\bar{c}$; parachute C_D = 0.5]

R - right u - up U - inner wing up
L - left d - down D - inner wing down

Spin no.	Spin block	Spin characteristics				Control deflection, deg (For spin / For recovery)			Parachute		Turns for recovery
		α, deg	φ, fps	V, deg	Ω, sec/turn	δ_r	δ_e	δ_a	Diameter, ft	ℓ, ft	
66		63	7U 5D	136	2.1	25L	23d	L23u R13d	9.3	25.0	$3\frac{1}{4}$, $3\frac{1}{2}$, $3\frac{1}{2}$, 4
65		63	7U 5D	136	2.1	25L	23d	L23u R13d	9.7	25.0	2, $2\frac{1}{2}$, $2\frac{1}{2}$, $2\frac{3}{4}$
67		63	7U 5D	136	2.1	25L	23d	L23u R13d	10.6	25.0	$2\frac{3}{4}$, $2\frac{3}{4}$, $3\frac{1}{4}$
69		63	7U 5D	136	2.1	25L	23d	L23u R13d	11.3	25.0	2, 2, 2
70		63	7U 5D	136	2.1	25L	23d	L23u R13d	12.1	25.0	$1\frac{1}{2}$, $1\frac{3}{4}$, $1\frac{3}{4}$
71		63	7U 5D	136	2.1	25L	23d	L23u R13d	11.3	40	$2\frac{1}{4}$, $2\frac{1}{4}$, $2\frac{1}{4}$
72		63	7U 5D	136	2.1	25L	23d	L23u R13d	11.3	35	2, 2, $2\frac{1}{4}$, $2\frac{1}{4}$
73		63	7U 5D	136	2.1	25L	23d	L23u R13d	11.3	30	2, 2, 2, 2, $2\frac{1}{4}$
74		63	7U 5D	136	2.1	25L	23d	L23u R13d	11.3	20	2, 2, 2
76		64	7U 5D	139	2.0	25L	23d	L23u R13d	11.3	25	2, 2, 2
77		63	0	144	2.3	25L	23d	L23u R13d	11.3	25	$1\frac{1}{4}$, $1\frac{1}{2}$
28		61	3U 7D	144	2.3	25L	23d	L23u R13d	11.3	25	$1\frac{1}{2}$, $1\frac{1}{2}$, $1\frac{3}{4}$
[a]208		64	1D	136	2.2	25L	23d	L13d R23u	11.3	25	$1\frac{1}{2}$, $1\frac{3}{4}$, 2
[a]229		55 68	14U 9D	152	2.3	25L	23d	L13d R23u	11.3	25	$1\frac{1}{2}$, [b]2
[c]276		61	5U 2D	131	1.9	25L	23d	L13d R23u	11.3	25	$\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{2}$

[a]Long rudder and increased rudder chord; 20° elevator cutout.
[b]From visual observation.
[c]Long rudder and increased rudder chord; c.g. = 0.17$\bar{c}$.

TABLE 18.- RESULTS OF SPIN-RECOVERY PARACHUTE TESTS FOR INVERTED SPINS

[Configuration as noted; weight, 4520 lb; c.g. = $0.222\bar{c}$]

R - right　u - up　U - inner wing up
L - left　d - down　D - inner wing down

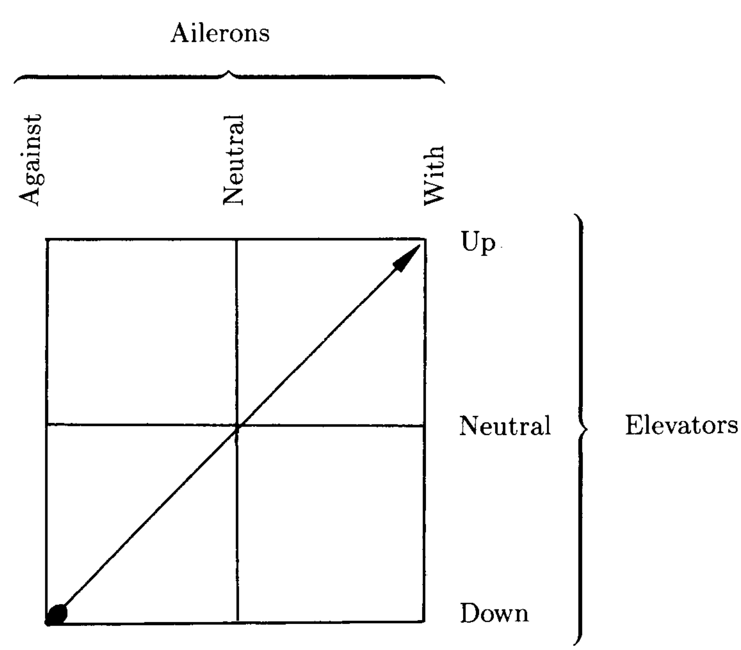
Spin no.	Spin block	Spin characteristics				Control deflection, deg (For spin / For recovery)			Parachute		Turns for recovery
		α, deg	ϕ, deg	V, fps	Ω, sec/turn	δ_r	δ_e	δ_a	Diameter, ft	ℓ, ft	
209		-32 -56	0 23D	168	2.7	25R	23d	L23u R13d	13.3	25.0	>3, >6, >20
210		-32 -56	0 23D	168	2.7	25R / 0	23d	L23u R13d	13.3	25.0	$\frac{1}{2}$, 1, 1
213		-32 -56	0 23D	168	2.7	25R			12.8	25.0	>4, >10
214		-32 -56	0 23D	168	2.7	25R	23d	L23u R13d	14.7	25.0	>4, >20
212		-32 -56	0 23D	168	2.7	25R	23d	L23u R13d	15.7	25.0	$\frac{3}{4}$, $\frac{3}{4}$, [a]1
228		37 56	2U 21D	179	2.9	25R / 25L	23d / 0	L23u R13d	13.3	25.0	$\frac{1}{4}$

[a]From visual observation.

Chart 1. Description of Recovery Techniques Used in Charts

a. Smooth spin mode.
b. Recovery turns obtained from visual observation.
c. Recovery attempted by deflecting the rudder to full against the spin, the ailerons to neutral, and the elevators full up.
d. Recovery attempted by deflecting the rudder to full against the spin and ailerons and elevators to neutral.
e. Recovery atempted by deflecting the rudder to full against the spin, the ailerons to neutral, and the elevators to full down.
f. Recovery attempted by deflecting the rudder to full against the spin, the ailerons to full with the spin, and the elevators to neutral.
g. Recovery attempted by deflecting the rudder to full against the spin, the ailerons to full with the spin, and the elevators to full up.
h. Recovery attempted by deflecting the rudder to full against the spin, the ailerons to full with the spin, and the elevators to full down.
i. After launching rotation stops, the model enters a steep spiral.
j. After launching rotation stops, the model enters a steep rolling dive.
k. Recovery attempted by deflecting all controls to neutral.
ℓ. All controls set at zero deflection.

Example of spin block



The control block shows that the model controls are set with elevators down and ailerons against. For recovery, the controls are moved to ailerons full with and elevators up.

Chart 2. Spin and Recovery Characteristics of Model in Basic Configuration

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Altitude		Loading
Australian basic trainer	Erect	15 000 ft	Basic configuration	IYMP = -180×10^{-4} c.g. = $0.222\bar{c}$

Model values converted to full scale U - inner wing up D - inner wing down Numbers outside blocks indicate test numbers

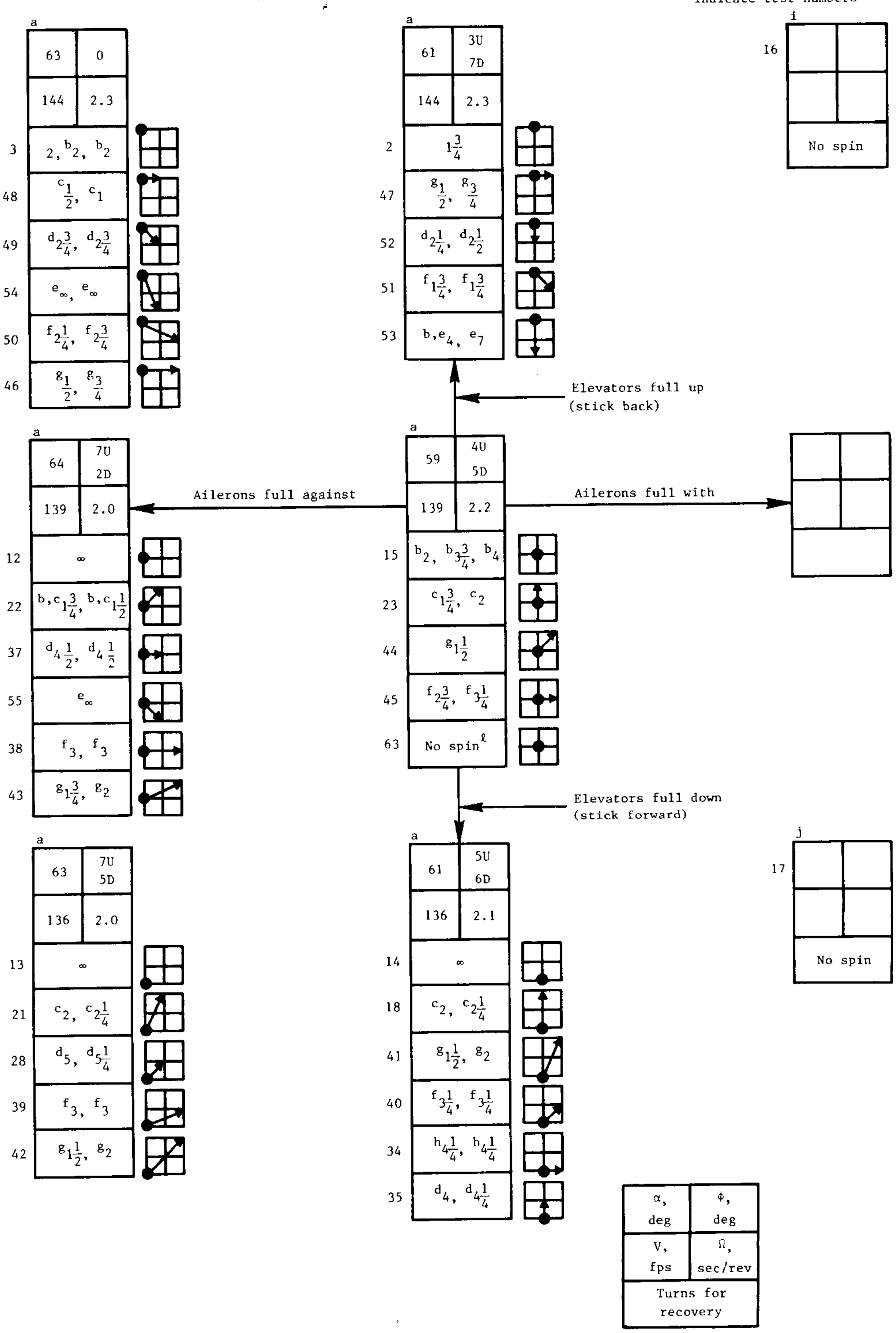


Chart 3. Spin and Recovery Characteristics of Model in Basic Configuration With Long Rudder and Increased Rudder Chord

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Altitude		Loading
Australian basic trainer	Erect	15 000 ft	Basic with long rudder and increased rudder chord	$IYMP = -180 \times 10^{-4}$ c.g. = $0.222\bar{c}$

Model values converted to full scale U – inner wing up D – inner wing down Numbers outside blocks indicate test numbers

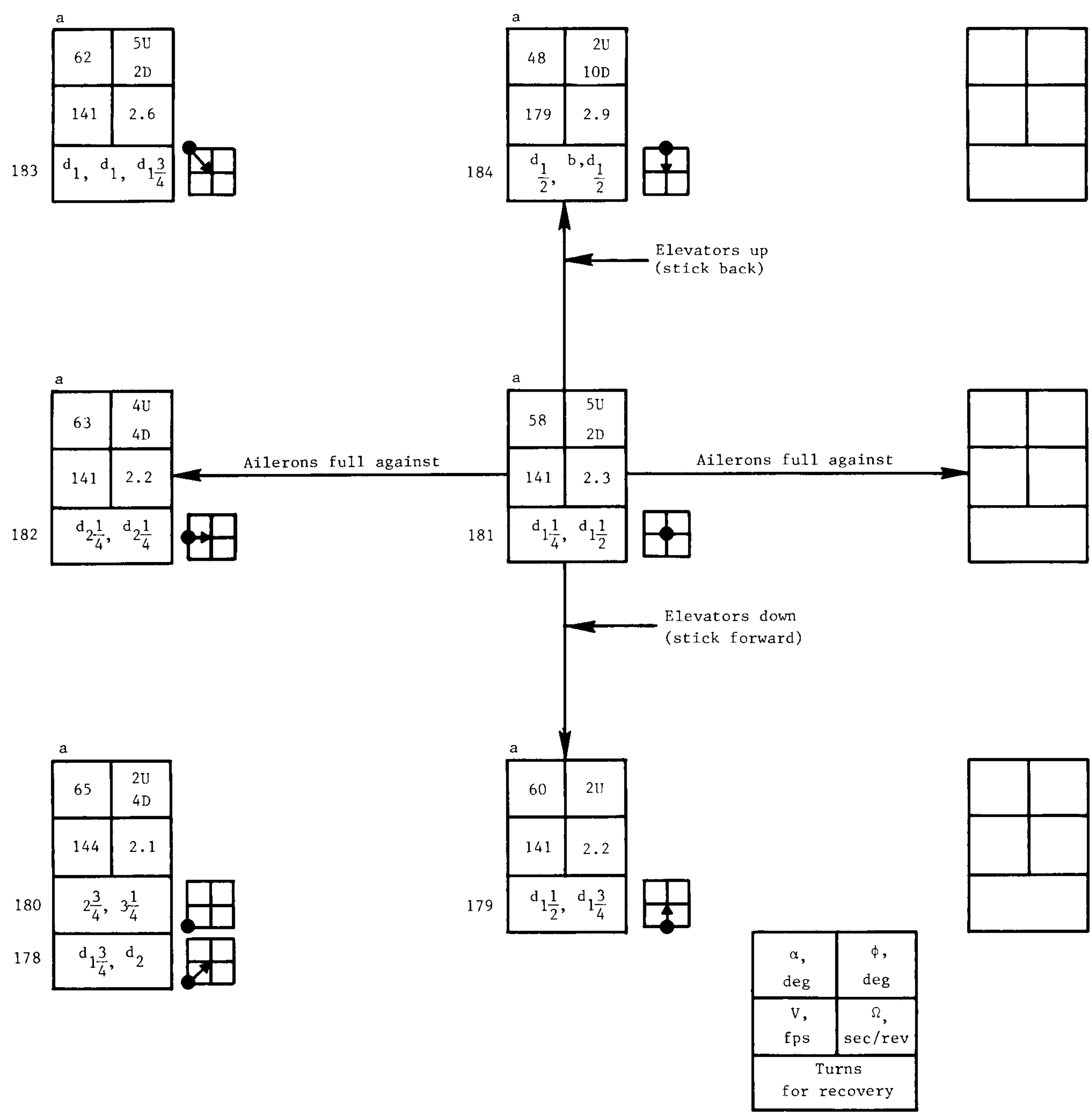


Chart 4. Spin and Recovery Characteristics of Model With Long Tail Configuration

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Altitude		Loading
Australian basic trainer	Erect	15 000 ft	Long tail configuration	IYMP = -156×10^{-4} c.g. = $0.236\bar{c}$

Model value converted to full scale   U - inner wing up   D - inner wing down   Numbers outside blocks indicate test numbers

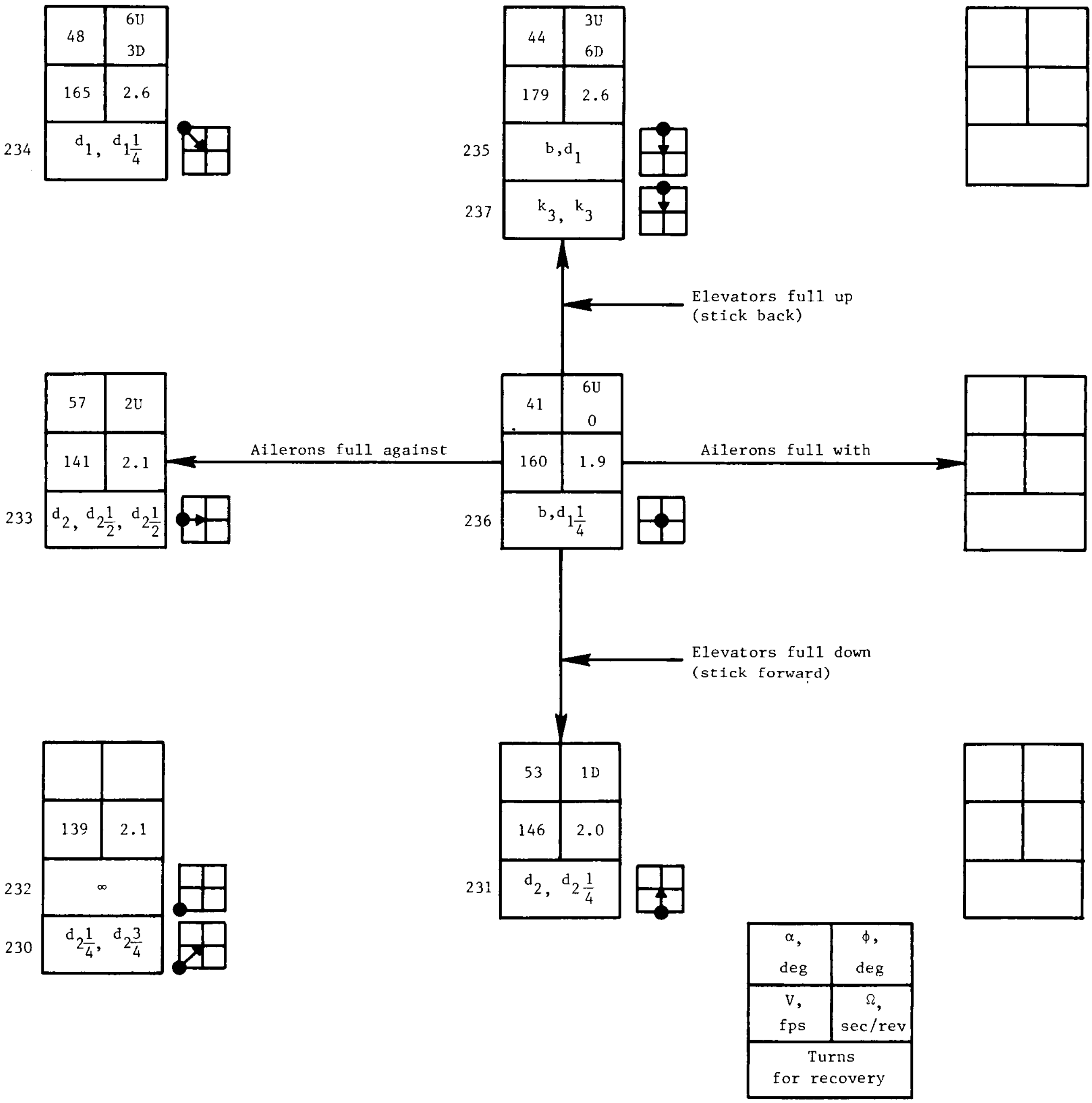
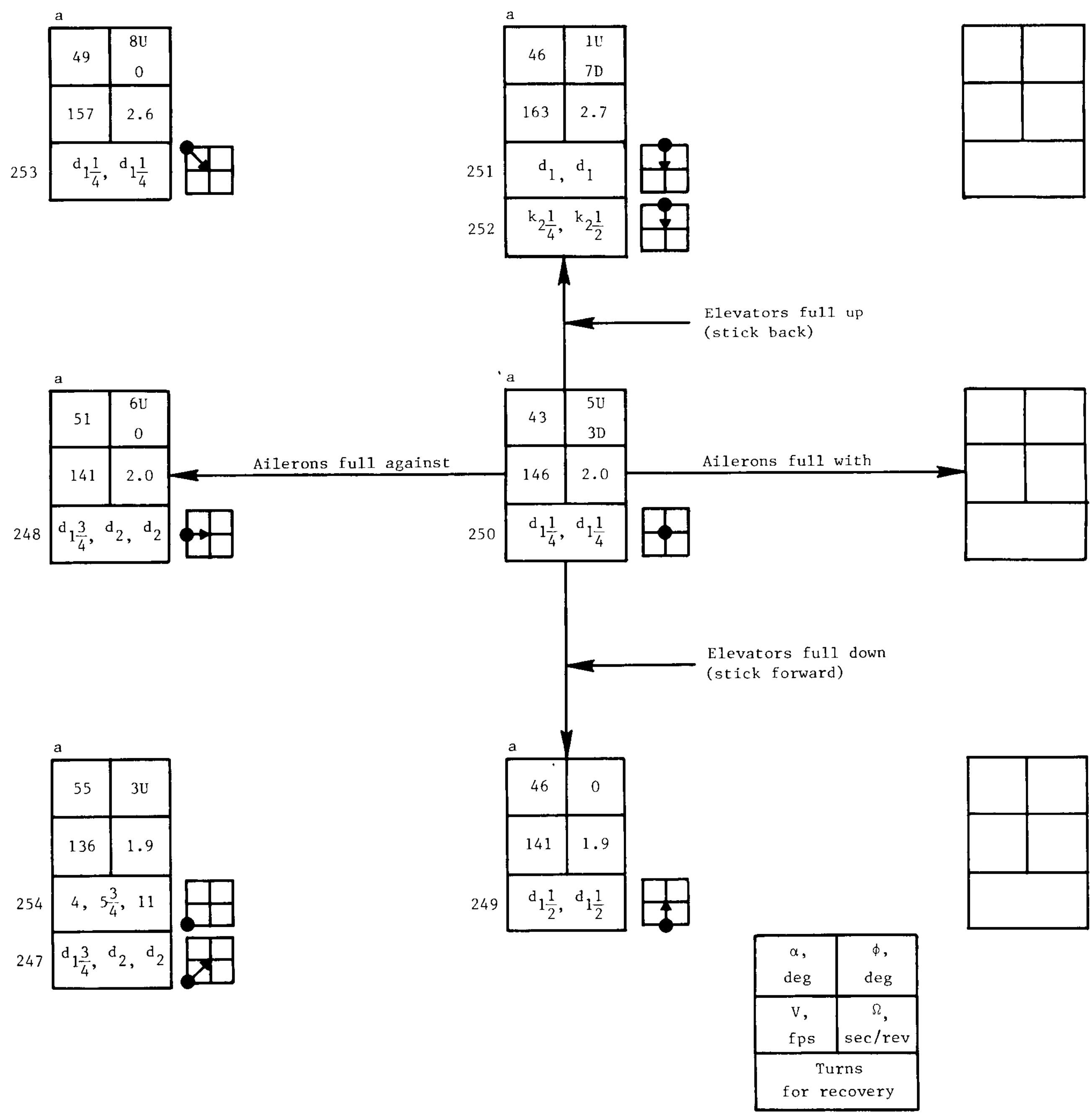


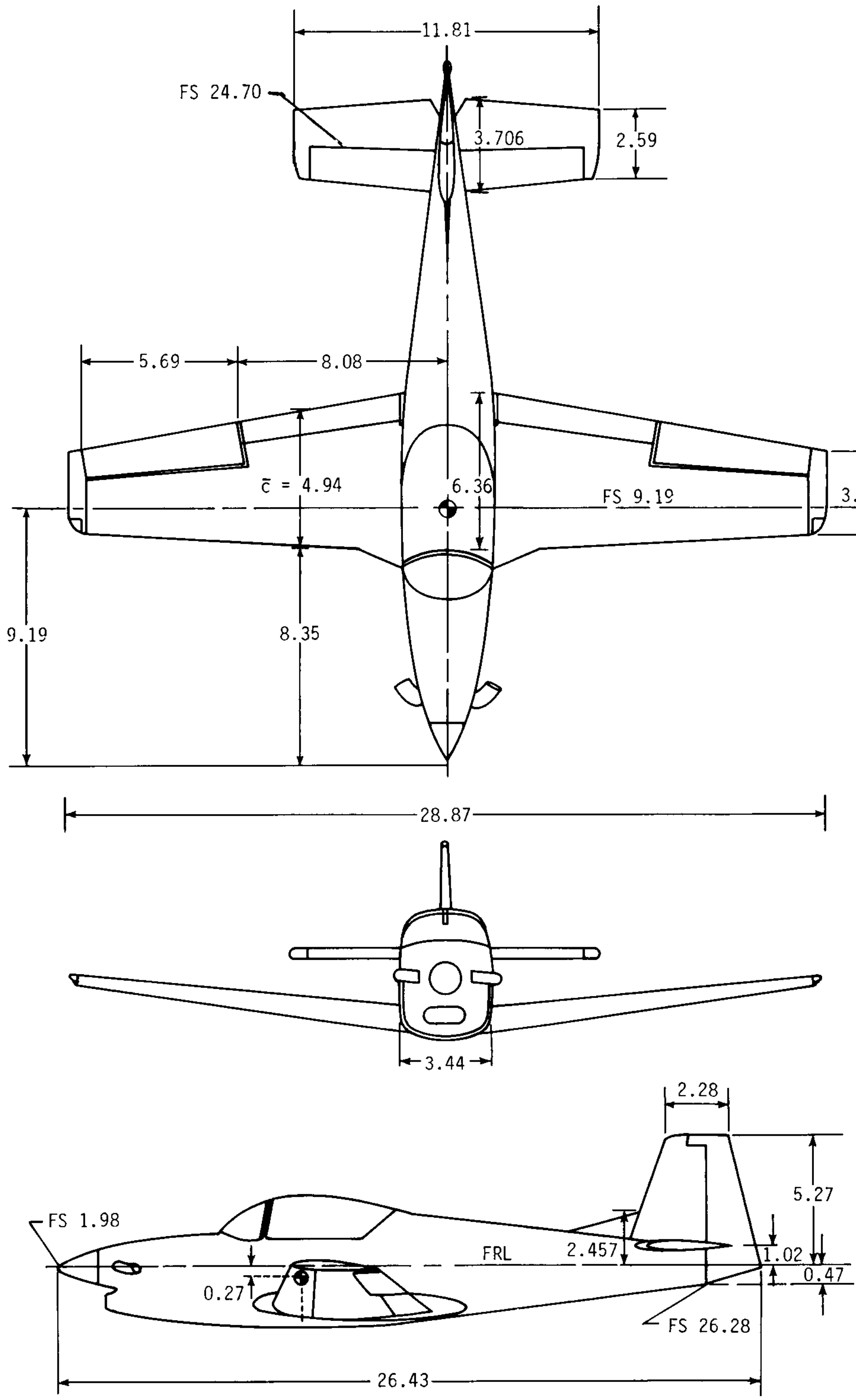
Chart 5. Spin and Recovery Characteristics of Model With Long Tail With Increased Rudder Chord

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed spin data presented for, rudder-full-with spins)]

Airplane	Attitude	Altitude		Loading
Australian basic trainer	Erect	15 000 ft	Long tail with increased rudder chord	IYMP = -156×10^{-4} c.g. = $0.236\bar{c}$

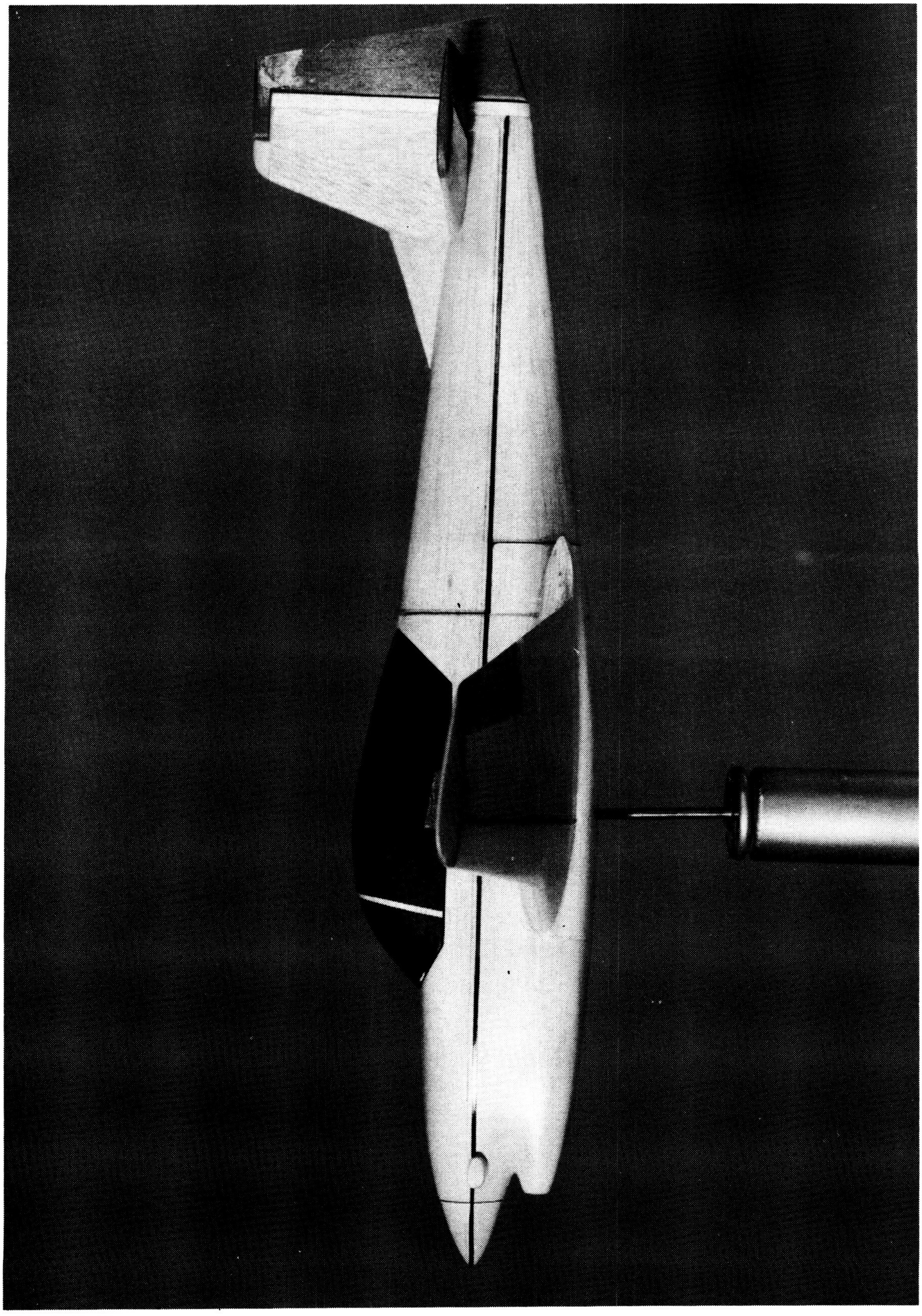
Model values converted to full scale U - inner wing up D - inner wing down Numbers outside blocks indicate test numbers





(a) Three-view drawing.

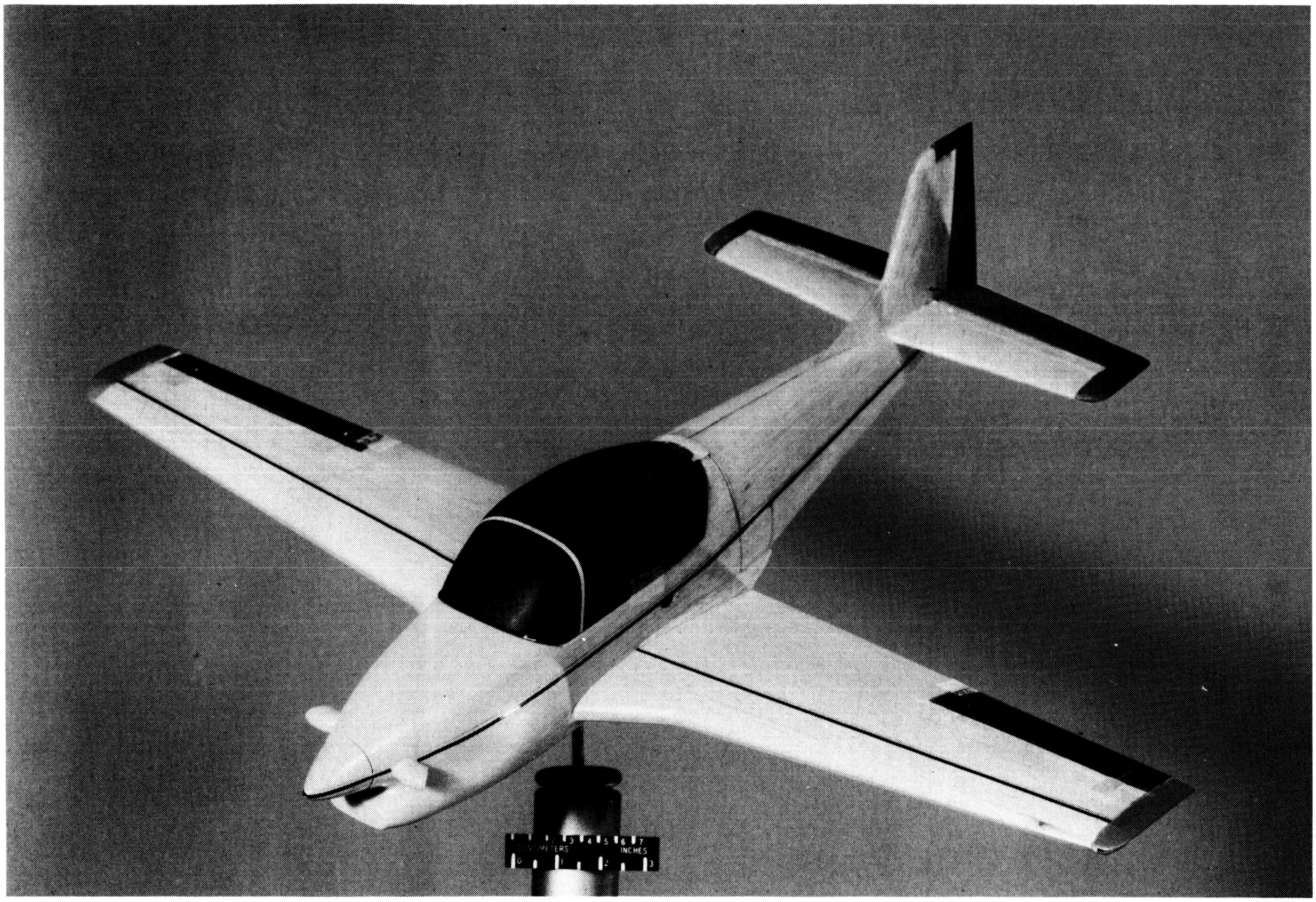
Figure 1. Three-view drawing and photographs of Australian trainer model. 1/15-scale basic configuration; c.g. = $0.17\bar{c}$; linear dimensions are given in inches.



L-84-3433

(b) View from side of basic configuration.

Figure 1. Continued.



L-84-3432

(c) View from front of basic configuration.

Figure 1. Concluded.

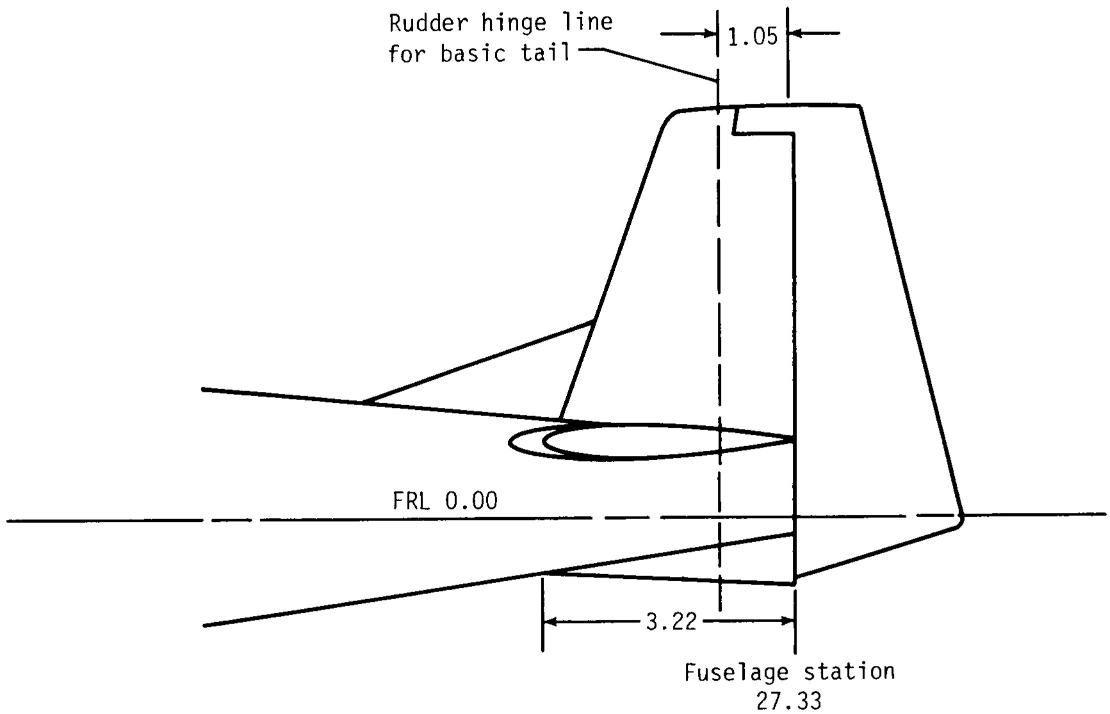


Figure 2. 1/15-scale long tail configuration. Linear dimensions are given in inches.

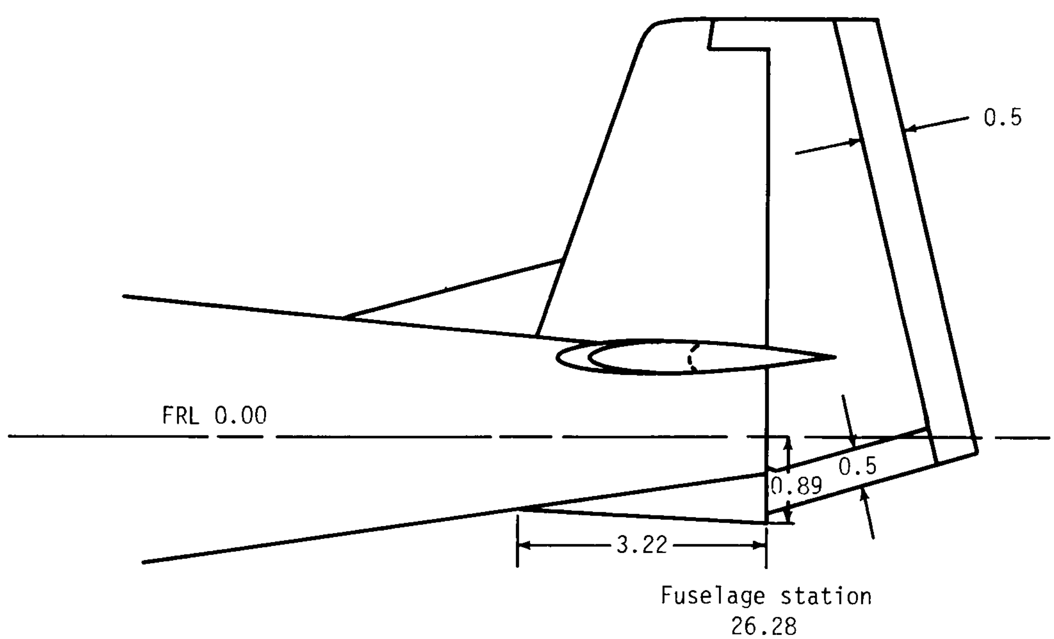


Figure 3. 1/15-scale basic vertical tail with increased rudder length and chord plus a ventral fin. Linear dimensions are given in inches.

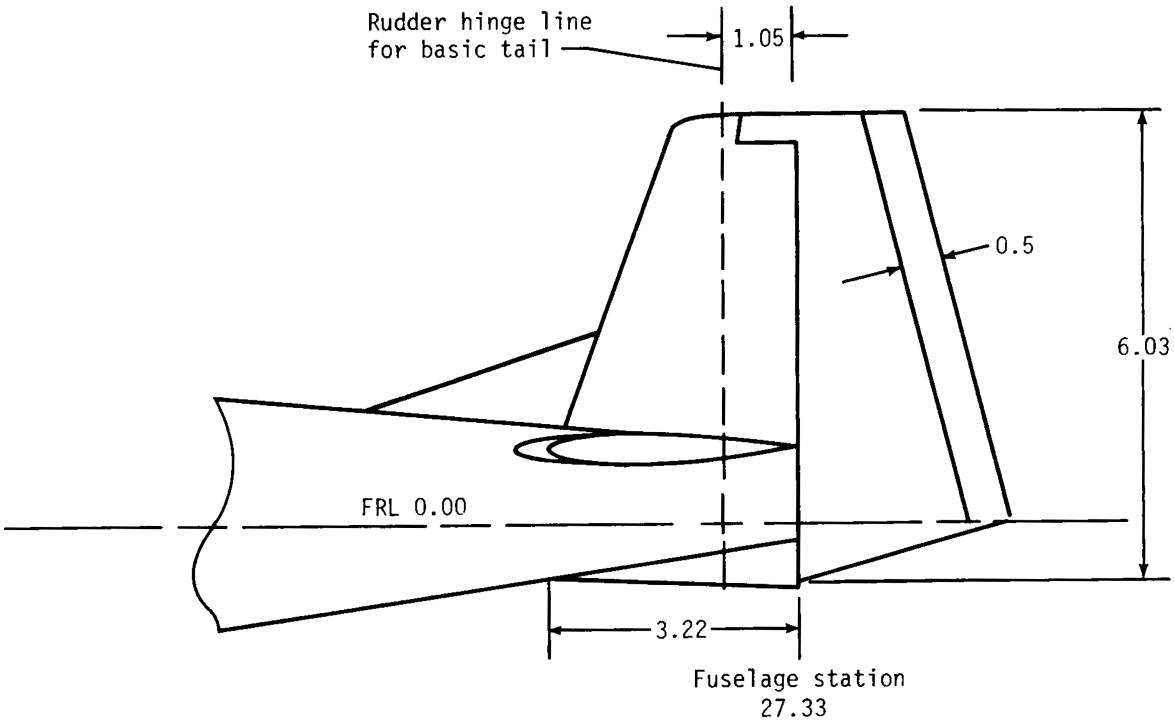


Figure 4. 1/15-scale long tail with increased rudder chord. Linear dimensions are given in inches.

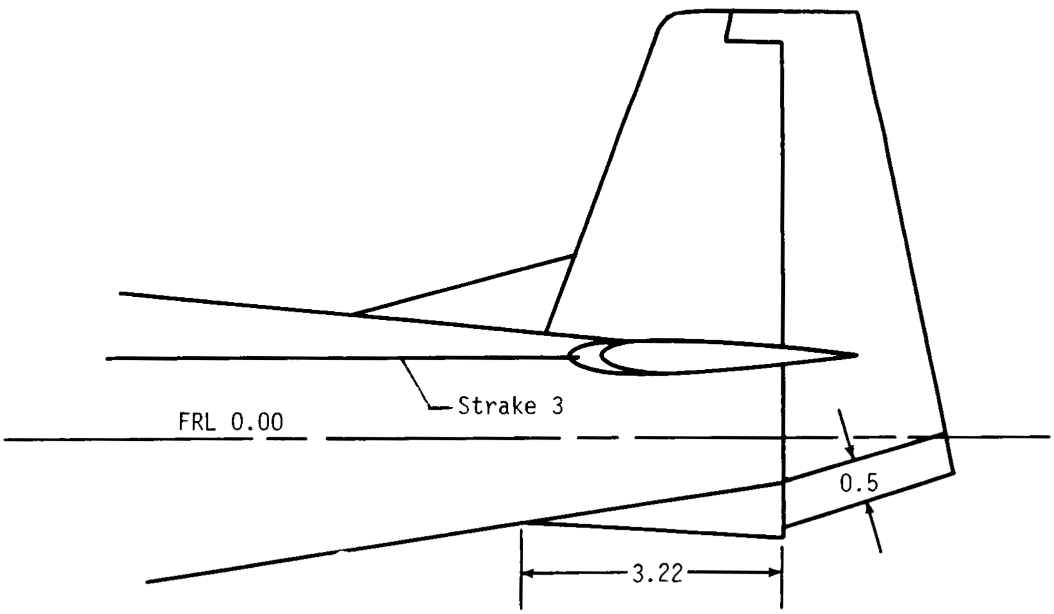


Figure 5. 1/15-scale basic rudder with increased length. Linear dimensions are given in inches.

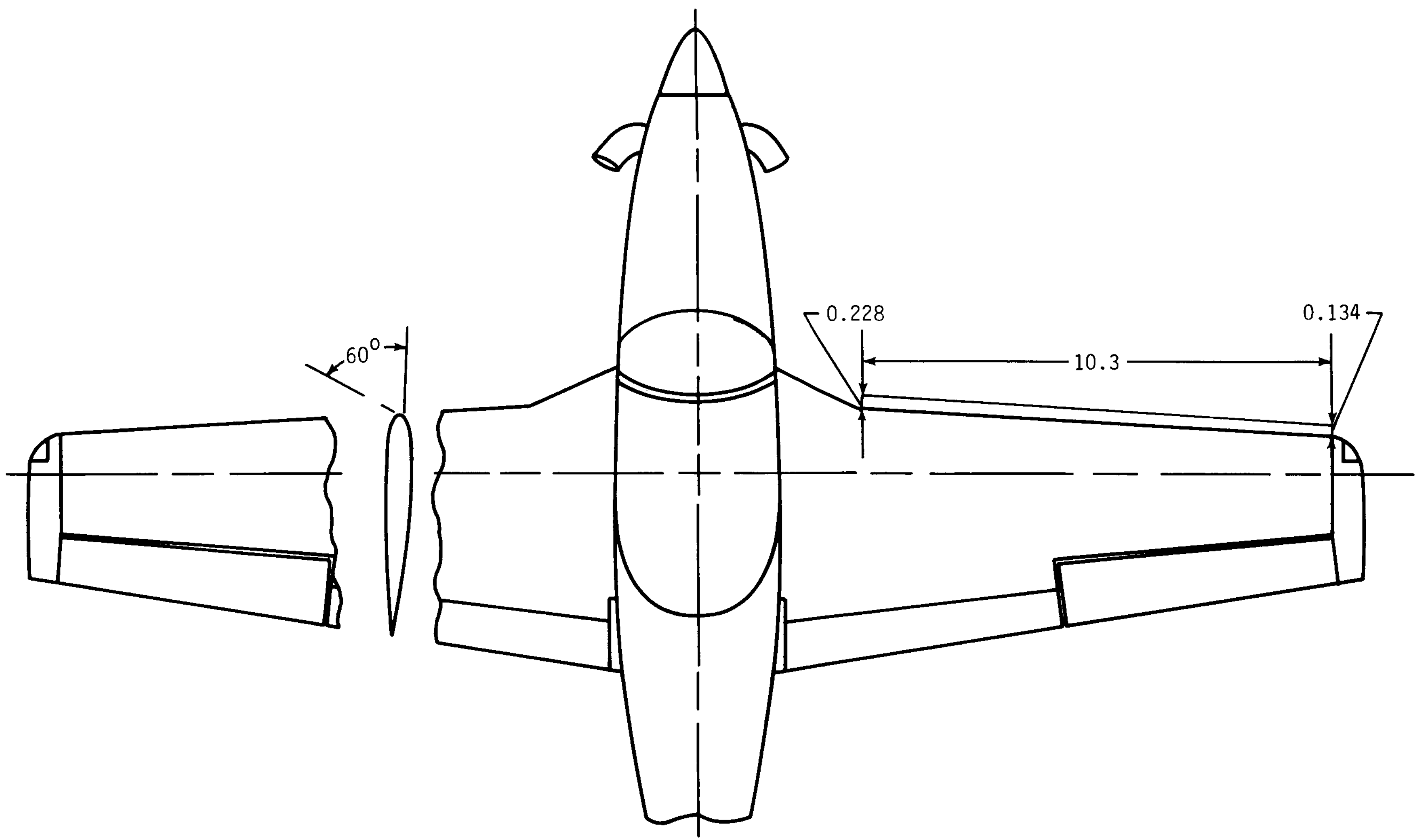


Figure 6. Leading-edge Krueger flaps tested on 1/15-scale model. Linear dimensions are given in inches.

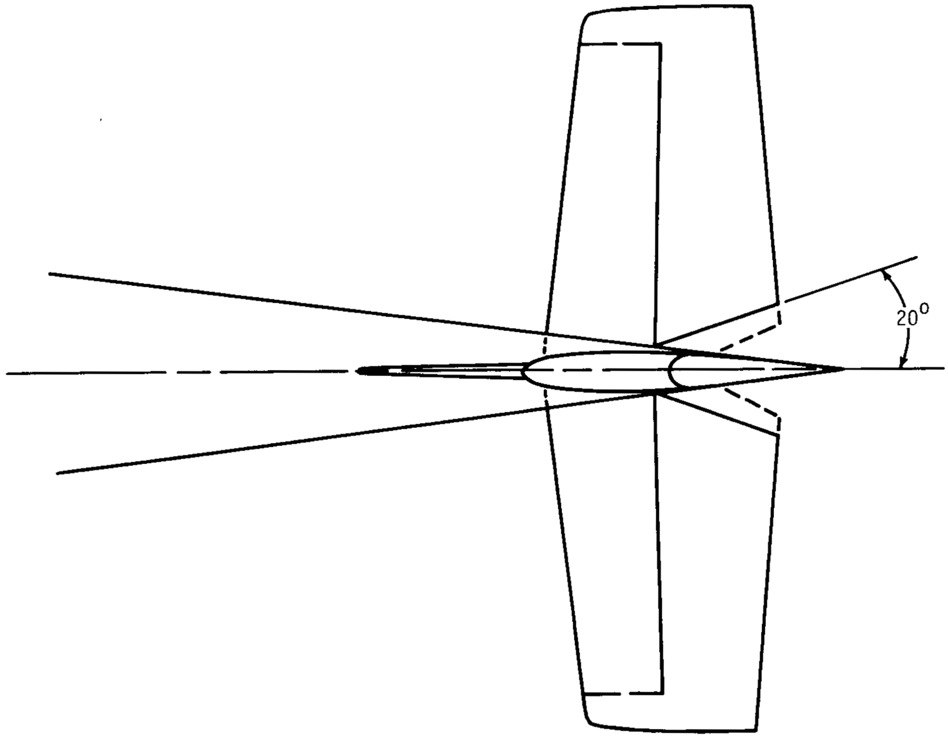


Figure 7. 20° cutout for elevator.

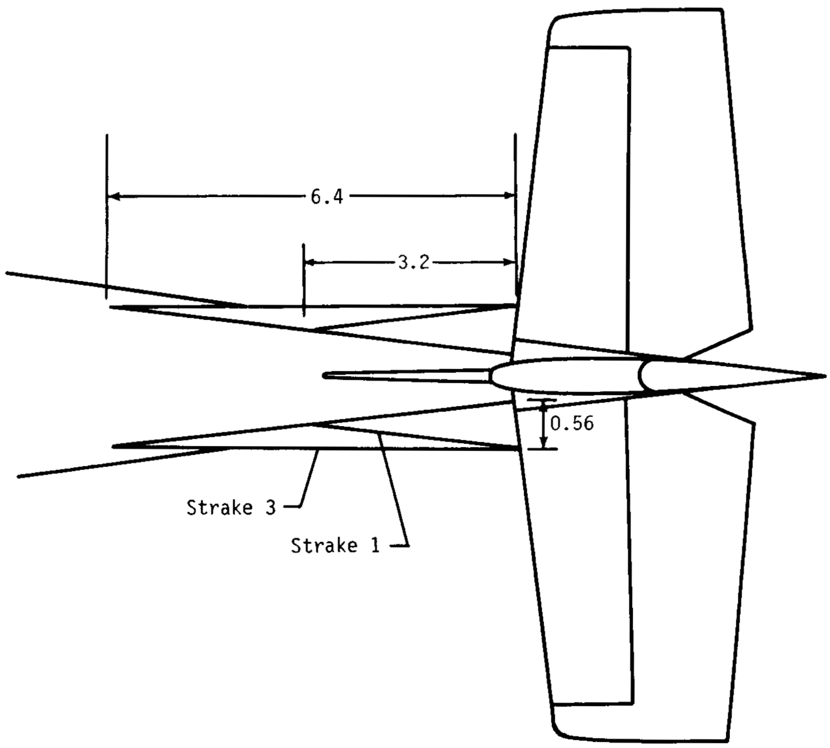


Figure 8. Strakes tested on 1/15-scale model. Strakes are aligned with horizontal tail; linear dimensions are given in inches.

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-89049		

4. Title and Subtitle
Spin-Tunnel Investigation of a 1/15-Scale Model of an Australian Trainer Airplane

5. Report Date
May 1987

6. Performing Organization Code

7. Author(s)
James S. Bowman, Jr., Raymond D. Whipple, and William L. White

8. Performing Organization Report No.
L-16191

9. Performing Organization Name and Address
NASA Langley Research Center
Hampton, VA 23665-5225

10. Work Unit No.
505-61-41-01

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, DC 20546-0001

13. Type of Report and Period Covered
Technical Memorandum

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
An investigation has been conducted in the Langley Spin Tunnel to determine the spin and spin-recovery characteristics of a 1/15-scale model of an Australian trainer airplane. The investigation included erect and inverted spins; configuration variables such as a long tail, fuselage strakes, 20° elevator cutouts, and rudder modifications; and determination of the parachute size for emergency spin recovery. Also included in the investigation were wing leading-edge modifications to evaluate Reynolds number effects. The results of the investigation indicate that the basic configuration will spin erect at an angle of attack of about 63° at about 2 to 2.3 seconds per turn. Recovery from this spin was unsatisfactory by rudder reversal or by rudder reversal and ailerons deflected to full with the spin. The elevators had a pronounced effect on the recovery characteristics. The elevators-down position was very adverse to recoveries, whereas the elevators-up position provided favorable recovery effects. Moving the vertical tail aft (producing a long tail configuration) improved the spin characteristics, but the recoveries were still considered marginal. An extension to the basic rudder chord and length made a significant improvement in the spin and recovery characteristics. Satisfactory recoveries were obtained by deflecting the rudder to full against the spin and the elevators and ailerons to neutral.

17. Key Words (Suggested by Authors(s))	18. Distribution Statement
Spinning Spin tunnel Trainer airplane	Unclassified—Unlimited Subject Category 02

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	38	A03

NASA-Langley, 1987

For sale by the National Technical Information Service, Springfield, Virginia 22161-2171